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EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

Technical Education of the Engineer.—At the recent meeting of the Institute of Mining Engineers in this city, a discussion upon the subject of technical education was resumed from the Washington meeting of March last, and by invitation was participated in by members of the Society of Civil Engineers, thus obtaining opinions on this subject from the practical men of both of these branches of the profession. This discussion did not embrace all technical education, of which law or medicine, or surgery, with chemistry as an offshoot from the latter, are the older technical studies; but was limited solely to the recent additions to knowledge; which the modern developments of mechanical or industrial pursuits have produced. Neither was that most essential of all technical avocations, the writer or teacher, fully represented in the

expression of views, and the results of the consideration which they have been especially called to give to this subject, were not so fully expressed as could have been wished. The information elicited, therefore, was narrowed down to what, in the opinions of the practical engineers, should be the proper acquirements of a young man in learning, precedent to the commencement of a career, upon which to predicate a ready and successful exercise of mining and civil *engineering ability*. The recognition that mathematical attainments of a high order were as desirable, if not needful, to the engineer as the ability to use a language and write it out is to a poet, was, if not asserted in these words, a fair statement of the conclusions of most of the speakers. The corresponding averment that mathematical or other intellectual attainments would *not* qualify a man to be an engineer, any more than the most thorough knowledge of the dictionary and grammar would confer the poet's faculty, was *not* so definitely averred.

The sense of deficiency in both general and particular knowledge was the uniform admission of all the speakers, who were, for the most part, the older and most experienced practicing engineers of the day. Forty years ago the profession was scarcely to be be considered what was then called a "liberal one." The collegiate course of that time, which gave a smattering of chemistry and physics, with, however, a very fair course of higher mathematics (with a somewhat inadequate presentation of applied mechanics especially referred to forces of moving bodies), was not thought to be part of the requisite education of the foreman mechanic, which was about the standing of the engineer of the time. Most of the older engineers of to-day (who were the scholars of forty years ago) are men who from mere force of personal ability have attained their present position, and who by intuitive knowledge—by experience and personal observation rather than by study, and by incessant and arduous labor, have built up their reputations. Those who have reached eminence have inevitably come to appreciate the learning of the schools, and have availed themselves of any aid and all means in following out their undertakings; the mathematician, the physicist, the chemist, the geologist or the linguist, all have been employed as occasion demanded, in the same way that labor has been used or material purchased. Still the *want of information* has been seriously felt when prompt action or independence of thought were requisite. Errors in plan and in construction, in comprehension

originally, or accomplishment in the end, always difficult to obviate, and sometimes even when trivial, insurmountable, have embittered the life of the most successful director of work. Each engineer knows in his heart how close upon failure, constructedly or financially, his most successful and esteemed undertaking or accomplishment has at one time hung in the balance, and how the defect which formed the obstacle to be overcome or palliated was one which *knowledge* would have avoided. Where the knowledge, which was at such a moment so essential, was to be found—in whose teaching, or whose practice, in what book, or from whence to have been derived—from what course of study, even in what language, could not be designated, and it was, consequently, generally concurred in by all speakers, that the broadest and most general education was not too extensive in its scope for the foundation of a young engineer's career!

This happy conclusion leaves the main point as inconclusive as ever.

The technical education for an engineer that is really to be considered, is necessarily a limited one. It is how to impart in a four years' course to a young man who has had a common school education, which has developed little more than mnemonic ability, and the semblance of deportment, but whose friends have decided to educate for an engineer, the *essential* mathematical, physical, and other knowledge which every day's practice of the profession will call into use, and as much more for "breadth" as the capability of the pupil will admit. It is to be regretted that the common school education does not develop or foster latent powers, so that the youth of sixteen to seventeen years of age, who has completed his "course," and is a candidate for the freshman class of the "Technical School," although he may actually be in possession of that mathematical or mechanical *ability* which alone will ensure a successful career in the engineering profession, yet unless highly marked in the boy (when it is generally erratic in the man), will have given few outward indications in advance of the completion of studies, on which even a guess as to suitableness of avocation can be based.

It is a serious subject for comment as to whether the progress of the common school system in its rigid uniformity, is not retarding the especial growth of individual ability, and forming a limit to our higher advances in knowledge. Both mathematics and the languages, require that more than a foundation should have been attained by the youth of sixteen or seventeen, if he is to be eminent in them in future

years. Especially the mathematical capacity, which is so essential to the engineer, can be fostered and developed in the boy, but it cannot be taught. Not one-half of all the pupils of the schools in the land can comprehend the processes of simple arithmetic. The attempt was made with Colburn's arithmetics, thirty or forty years since, to teach the relations of figures by pure reasoning alone, with admirable success for one-third the scholars, by great drilling with another third, and with complete failure for the remainder; until after many years' trial, the system of rules, with explanations to those who could understand, was again returned to. For the purpose of every day life the rule, even with only a semi-consciousness of reason for it, at one time in one's boyhood, will answer; but for aptitude in the use of figures, such a knowledge as never calls for the recollection of words, however expressed, is indispensable, and for progress in studies, the learning of a rule is a detriment to the reasoning faculty.

The youth who are entered to our technical schools with a view of becoming engineers, are unquestionably selected with some regard to their capacity to receive the peculiar instruction, while examination puts out many that are incapable or deficient; still the fact remains that the standard for admission is undeniably low. It would be very well if in the upper schools of our common school system, and as for that matter, if from the primary schools upwards, more attention could be given to the education of individual pupils, so that the point of departure of technical school education of all kinds could be elevated from the present one. Could this be effected, the entire character of our national collegiate education would be placed in better accordance with that of other civilized lands than at present. . . .

There is another aspect of this subject of engineering education, singularly not referred to by any of the speakers; to which attention should be called, that is, the special requirements of a technical learning for engineers, which shall impart to the student the particular professional information which he should be taught. This proposition of teaching on engineering subjects involves three conditions: first, that there shall have been an observer, whose knowledge, both of methods and accomplishments, has taken the form of a *record;* second, that there shall have been an investigator, whose reasoning shall have enunciated a *science;* and third, that there shall have been an instructor, whose *theory* has comprehended the adapta-

tion of the recorded construction, and the application of the investigated science to other purposes or ends. The availability of the learning, in practical use to the student when he emerges as a graduate from the schools, depends upon the fulness and accuracy of the record—the thoroughness of the investigation—the soundness of the theoretic teaching. It is to be feared that the schools themselves have more knowledge to acquire from the practice of the engineer than they can impart to the pupil, who is expected to succeed and follow in that practice. The text books of all languages, and of the English language especially, are far from complete or accurate in their record, description or illustration of actual practice or results, in engineering or mechanism. Each new text book reproduces largely what the author considers available from older authorities, and errors or mistakes are perpetuated with the same fidelity that the correct, but possibly antiquated, schemes have been delineated or described; while the additions of new matter are rarely made with knowledge of the distinction between practice and project. The deficiency of text books is more marked in constructive details, the mastery of which is the test of all engineering, than in arrangement or disposition of parts, or in the whole of erections or machines. This want is so complete, that a thorough knowledge of book learning only graduates a pupil as helpless as if he were without hands. But the "science" of the text books, as applicable to the requirements of work, is by no means as reliable or trustworthy as could be desired. Much skill, ingenuity and ability have been evinced by the best writers, in the statement of physical laws in oracular words, happily expressed after the style of legal opinions, so that unnoticed qualifications shall be traps to those who endeavor to use them; but real error has not unfrequently accompanied the most dogmatic conclusions. At times, science has been a stumbling block and not an aid to the engineer.

Take for a ready instance, the demonstration, that the expansive effect of steam in a single cylinder engine was identical with that in the double or compound engine, which destroyed the prospects and broke the heart of Hornblower nearly 100 years ago. For 70 or 80 years the law of the force of expansion in a steam cylinder was taught in all the books as following the curve of hyperbolic logarithms, until about 1850 it was discovered that this curve did not at

all express the practical occurrence—some of the conditions of steam, heat and work had been unconsidered. It has been recognized at last that to impel a crank engine by means of a single cylinder with a high expansion, was or is, as practicable as to drive it by the fall of a pile driver ram. The mechanical effect of a sledge hammer is as surely expended on the anvil as it is represented by the lifting of the hammer before it fell; but he who should essay to turn a grindstone by hammering the crank would unfailingly come to grief, or at least the crank would, which is what happens to the single cylinder engine. The strength of beams may be taken as a ready instance of the incompleteness of theoretical investigation. We *know* the tensile strength of materials within limits of imperfections of the materials themselves, and the crushing strength within limits of those same imperfections as locally distributed in the length under compression; but the cross strength of even a perfectly homogeneous material can only be estimated by some hypotheses of neutral axis, which, neglecting the internal strains in a web, call for an assumption of a new tensile or compressive strength. To be sure the most thorough writers have indicated the correct method, in discussing this subject (Lamé on the Elasticity of solid bodies), but the text books teach with unqualified dogmatism.

The past hundred years have witnessed the growth of modern civil and mechanical engineering. The crude efforts of those who took the early steps can no longer be accepted as capable of giving distinction or position to our younger engineers. Telford is not an authority on bridge construction. Smeaton would be lost in designing a lighthouse. Watt would be incapable to construct a first-class modern engine. Stephenson would not now be trusted to construct a railway. Morse could not direct the running of a new line of telegraph. Daguerre would be lost in a photograph gallery. The initiatory labors of these great men are now a part of the history of engineering; their record forms a paragraph in the book which the young engineer must study. As surely as development and growth are processes of improvement and accretion, so surely does the progress of engineering in all its branches have its basis upon the preservation of present attainments by record, and making them available for future use by teaching to the student who shall become the engineer hereafter.

Franklin Institute.

HALL OF THE INSTITUTE, June 21, 1876.

The stated monthly meeting was called to order at 8 o'clock, P.M., Vice-President, Chas. S. Close, in the chair.

There were present 76 members and 9 visitors.

The minutes of the last monthly meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting the following donations were made to the library:

Thirteen Numbers of the JOURNAL OF THE FRANKLIN INSTITUTE for 1874–75. From Chas. Bullock.

Seventh Annual Report of the American Railway Master Mechanics' Association in Convention at Chicago, May 12th, 13th and 14th, 1874. Cincinnati, 1874.

Report of Proceedings of the Eighth Annual Convention of the American Railway Master Mechanics' Association held in the City of New York, May 11th, 12th and 13th, 1875. Cincinnati, 1875. From J. H. Setchel, Secretary.

Journal of the Royal Geographical Society. Volume 45th, 1875. From the Society, London.

Art Directory, containing regulations for promoting instruction in Art, with appendix.

Directory with regulations for establishing and conducting science schools and classes, &c.

A Guide to the South Kensington Museum, London. From C. B. Worsnop, S.K.M.

Archives du Music. Teyler. Vol. 4. Fasicule, premier, 1876. From the Directors.

Reports of the Secretary of the Treasury on the Construction and Distribution of Weights and Measures. Washington, 1857. Ex. Doc., No. 27, 34th Cong., 3rd Series. From J. E. Hilgard, U. S. Coast Survey.

Records of the Geological Survey of India. Vol. 8, Parts 1–4, 1875.

Memoirs of the Geological Survey of India, &c., &c. Jurassic Fauna of Kutch. Vol. 1, 2, 3, Series 9, 1875. From the Geological Survey Office of Calcutta, India.

Specifications and Drawings of Patents for Dec., 1875. From U. S. Patent Office, Washington.

New Encyclopædia of Chemistry, to be completed in 40 parts. Published by J. B. Lippincott & Co., Philadelphia. From the Publishers.

Notes on the Treatment of Mercury in North California. By T. Egleston, Ph.D. Philadelphia, 1876. From the Author.

Amphiorama ou la vue du Monde, par F. W. G. Trafford.

Further Notes on "Inclusions in Gems, &c.," by Isaac Lee, LL.D. Philadelphia, 1876. From the Author.

Verhandlungen des Naturhistorisch Medicinischen Vereins zu Heidelberg, neue folge, erster band, drittes heft, 1876. From the Society.

Solar Investigations, by John Erricson, LL.D. New York, 1876. From the Author.

Hand-book of Modern Steam Fire-engines, including the running, care and management of steam fire-engines and fire-pumps; by S. Roper. From Claxton, Remsen & Haffelfinger, Publishers, Philadelphia, 1876.

Food Chart; giving the names, classification, composition, alimentary value, rates of digestibility, adulterations, tests, &c., of the alimentary substances in general use. By R. Locke Johnson, London.

Statistics, Medical and Anthropological, of the Provost Marshal-General's Bureau; derived from records of the examinations for military service in the armies of the U. S. during the late war of the rebellion, of over a million recruits, drafted men, &c., &c. Compiled under direction of the Secretary of War by J. H. Baxter. In two vols. Washington, 1875. From J. H. Baxter, A.M., M.D.

A Brief Treatise on United States Patents, for Inventors and Patentees; by Henry and Chas. Howson, Philadelphia, 1876. From H. & C. Howson.

Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains; being the sixth annual report of Rossiter W. Raymond. Washington, 1874. From Chas. O'Neil, House of Representatives.

Papers read before the Pi Eta Scientific Society, 1876; Rensselaer Polytechnic Institute, Troy, New York, 1876. From the Society.

Centennial Newspaper Exhibition, 1876. Complete list of American newspapers, &c., compiled by G. P. Rowell & Co., N. Y., 1876. From the Compilers.

The order of business was changed so as to now take up deferred business, under which head the subject of the adoption of the Majority Report on the Metric System of Weights and Measures was taken up.

The questions being on Mr. Chabot's motion to still further divide Mr. Jones' motion, so as to make the question of the adoption of the

report one resolution, and sending a copy to the Boston Society of Civil Engineers another; it was adopted.

The question then recurred, on Mr. Jones' motion to adopt the Majority Report of the Committee on the Metric System of Weights and Measures, and it was being discussed when, on motion of Prof. Houston, the further consideration of the subject was postponed to the stated meeting in September.

The Secretary presented his Report, embracing an illustrated description of the stationary Dry Dock, recently completed at the ship yard of Messrs. Wm. Cramp & Sons in this city; the Hitchcock lamp for burning fat or greasy oils without chimneys.

The Secretary also made a Report of the progress being made by the "Penna. Museum and School of Industrial Art," as the representative of the Institute in Board of Trustees of that body.

The Secretary read a communication from the American Society of Civil Engineers, tendering to the Members of this Institute an invitation to visit and make use of its rooms in the west gallery of the Main Building at the Centennial Exhibition.

Mr. A. G. Buzby offered a plan for the rearrangement and classification of the awards (medals, &c.) of the Institute, which on motion was referred to the Committee on Sciences and the Arts.

Mr. Hector Orr offered a resolution, relating to the construction of a ship canal across the Isthmus of Panama, which, on motion of Prof. Houston, was laid on the table.

On motion, the meeting then adjourned.

J. B. KNIGHT, *Secretary.*

SPRING PROPULSION FOR STREET CARRIAGES.*

By EDW. H. LEVEAUX.

The following description in the language of an amateur in mechanics will, I hope, give an idea of the car and its machinery as patented by me on the 24th of September, 1873, and of the progress towards perfecting and introducing the same to this time.

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*From the *Journal of the Society of Arts*, May 12, 1876.

Some years back I was struck with the simplicity of the ordinary toy mouse, which by a few turns of a common watch key in the hands of paterfamilias gives so much pleasure to the younger members of his family; and it appeared to me, with an improved method of spring coiling and tempering, a carriage for passengers might be manufactured to run on the tramways and railways.

In application to the ordinary form of tramway carriage, I have utilized a portion of the space below the floor of the car for an arrangement of drums, or barrels, containing the springs, which may be placed transversely in two groups, or sets, suitably inter-connected so as to form one continuous volute, acting to generate revolutions of the driving wheel, and thus effect the propulsion of the car. At the terminal or intermediate stopping stations, the means of winding up and re-coiling the springs, are to be provided by a suitable fixed steam-engine, or other prime-motor, rotary motion being communicated by a shaft under the roadway to vertical spindles and geared wheels, which being thrown into temporary connection for the purpose with the spring barrels, will coil the springs until the requisite tension power is obtained.

Where the line is three or four miles in length, I shall require three engines; one at each end of the line, and one in the middle. Where stationary engines cannot be worked, it is my intention to employ portable engines, which can be brought to the winding-up barrels, and the process of winding gone through, during the collection of tickets and checking the number of passengers. I think it will be advisable that the places where these "wind-ups" occur should be stopping stations, where passengers may alight from or enter the carriages. These stopping-stations are quite the custom abroad, and it will facilitate the working of my spring-cars if adopted where my invention is used.

On country roads, where long distances have to be traversed, I propose using an auxiliary spring engine. This engine will be fitted with the most powerful springs we can obtain, with full reversing and brake power. At convenient sidings on the route, and where it is calculated the spring power under the car will be expended, one of these auxiliary engines will be attached, which will draw the car a considerable distance, where another may be in readiness to continue or finish the journey, as the case may be. Should it be desirable on

some lines to have several cars drawn at once, I am of opinion the auxiliary engine can be fitted with sufficient power to draw, at a moderate speed, several such light cars with passengers; but this is a matter for consideration after my system has had a fair trial on the public tramways, with the style of car at present in use.

I commenced operations about August, 1873, and after trying some experiments on a paper car, with ordinary watch springs, I took out my patent in September of that year. At that time the largest springs made, were used for the purpose of lifting "Clark's patent iron shutters," and were about 6 lbs. in weight, giving a maximum pull of about 120 lbs. On visiting Sheffield, and seeing several of the most important steel and spring makers, I was informed springs of almost any size might be made, but fresh machinery (and some of a very costly character) and furnaces, etc., would have to be constructed, and none felt inclined to take this risk. I was ultimately introduced to the managers of the Titanic Steel Works, who undertook to provide springs for a rough trial; finding, however, their plant was incapable of turning out the steel required, they handed the matter over to the Phœnix Bessemer Steel Company. Mr. Thomas Hampton, the enterprising managing director, called on me, saw my model, and after due consideration, he assured me that with practice, and after experiments were made as to the exact quality of the steel required, almost any kind of springs could be rolled and tempered, and he at once undertook the affair.

Early in 1874 large springs were tested, and the car propelled by them on a short line laid down at my engineer's in the Borough, but after many experiments it was found the original iron barrels, and the machinery altogether, were too heavy to warrant a public trial of the car; sufficient, however, had been done to show the great stride made in spring tempering since the date my patent was taken out. We had already obtained a few springs with sufficient power to propel on the short line at the works, a heavily built truck, containing the spring boxes and machinery.

It was rather an amusing scene, however, this first run. Several of the men at the works were kind enough to volunteer as passengers for the first ride, not thinking the machine would develop so much power. On starting, the clutch was removed, and off the truck went; it, however, to use the words in which the circumstance was reported

to me, "started off at a rapid speed, and struck a plank placed at the end of the line with such violence as to throw itself off the line," together with my unfortunate friends, the workmen, who had so kindly given their services for the first trial. They picked themselves up with much good humor, and soon assisted to replace the car, all present being pleased that the machine had shown itself of so lively a character; and feeling satisfied with such a power properly developed, a great future must be the result of these experiments.

After this trial, long and many vexatious delays occurred before I induced the well-known spring makers, Messrs. George Salter & Co., of West Bromwich, to take up the matter. They laid down fresh machinery, and built new furnaces, securing the experience of their best hands in coiling and tempering large springs, and I am happy to say with great success. During the year 1875 many sets of springs were made and fixed under the car, which about May last was taken to West Brompton, and tried on the line at the Lillie-bridge Railway Works. At one trial we carried about five tons seven cwt., including car, machinery and passengers, and at the rate of about seven miles an hour; but having only three barrels at work, instead of twenty-four, we only made a proportionate distance.

Our first run on the rails took place at Lillie-bridge Railway Works one Saturday afternoon. The truck with the machinery fixed had, after some difficulty, been placed on the line, wound up, and brought to the starting place. It was anything but a pretty affair to look at, painted an ugly iron color; with its peculiar looking spring barrels underneath and between the wheels, and its long iron brake handle sticking up at one end, a more nondescript looking locomotive had never before, I should think, made its *debut* on the railway. It evidently puzzled the workmen and people engaged on the line, as, although it was Saturday afternoon, and the worksheds closed, a number of men and boys remained for two or three hours to see what our ugly customer was intended to do; when they discovered a "run" was to take place, and passengers wanted, a rush was made to secure seats, or, as I should more correctly say, stands, for the conveyance was not fitted for passenger traffic. Some sixteen men were soon standing in the truck and holding on to each other ready for starting. At this moment I was much amused at the con-

duct of the engineer and stoker on an engine shunting a long coal train, who had been requested to clear part of the line for my experimental run. They were sorely perplexed at seeing the men standing on what appeared to them a coal truck in difficulties, but no sooner did they perceive it start off with its motley group, without any apparent driving machinery, than they jumped off their engine and ran after the spring-car, climbing on the back, and taking part in its first journey along the line; and a very merry journey we had on our mongrel-looking carriage, the men and boys laughing outright at the comical appearance of the whole affair, at the same time expressing their pleasure at witnessing this novel kind of propulsion. "Only think, Bill," says one, "this 'ere truck being drove along by watch-springs."

Nearly three years have been spent in ascertaining the best method of tempering springs, and determining the most useful method of coiling the steel for my purposes. The time, however, has been most usefully employed in trials on my models and the truck and full-sized car at West Brompton. During this period some hundreds of different sized springs have been made and tested, and I may now fairly say all seeming difficulties have been overcome.

My spring makers, Messrs. George Salter & Co., have just completed the springs and machinery for propelling a car to run either on the asphalte roads or the ordinary tramways. Two sets of wheels have been made, which can be changed as required for either mode of transit. The car has been built especially for this machinery, the barrels placed longitudinally under the carriage, and in two sets, which can be worked successively or simultaneously, as the case may require. The spring power can be shut off at any time during transit, so as to take advantage of the impetus given to the car, and can be immediately applied when needed; full brake power is provided, together with a reversing gear, which has been greatly improved since the experiments made at Lillie-bridge.

The following comparison between the car tried at West Brompton and the one under construction by Messrs. Geo. Salter & Co., will show the improvements made during the last few months both in spring power, and in the style of carriage to be used either on the ordinary tramways or asphalte roads:

The body of the car tried at West Brompton weighed about 23 cwt.	The body of the car now constructed weighs 4 cwt.
The springs each weighed 120 lbs.	The springs each weigh 85 lbs.
The springs were each 65 ft. long and 4½ inches broad.	The springs are each 38 ft. in length, and 4 inches broad.
And had a maximum pull of 950 lbs.	And have a maximum pull of 1600 lbs.
Giving (each spring) 4½ revolutions.	Giving each spring over 7 revolutions.
These springs required boxes of 22 inches diameter.	These springs require boxes of 14 inches in diameter.

Thus, it will be seen the new car is about one-sixth of the weight of the one experimented upon last year, while it is nearly double the power and revolutions in the springs, with one-third less weight in springs and machinery. The barrels being arranged longitudinally under the car, give more room for the action of the brake and reversing gear.

As regards the important item of cost of machinery for driving a car by my spring-motors, and the annual cost of working a car on any of the London tramways by horse-power, it is estimated the expense of the latter is about £750 per annum, which includes keep of 14 horses, wear and tear and loss of stock (which I hear is very great), harness, stablemen, veterinary charges, rent, etc.; whereas it will be seen from the following estimate, my car can be worked at less than one-third of this annual expense:

The machinery for each car (which it is estimated will last many years), about £200.	
Interest on this outlay at 10 per cent., ...	£ 20
Proposed royalty on each car using my invention, per annum	100
Wind-up steam apparatus divided among cars in one of the metropolitan tramways, say per annum, ...	50
To make up round numbers, may be added for repairs, lubricating, and wear and tear, per annum, ...	30
Total expense of each spring-car per annum, . .	£200

Against £750 per annum for horse traction.

The price of the spring-motor (£200) is not carried forward into the yearly charges, as it will form part of the rolling-stock of the company. The "winding-up" is managed by a 5-horse power engine in about two minutes. Where the line is over three miles it will require three engines, which will be capable of winding up at least 200 cars daily.

Book Notices.

UNITED STATES PATENTS.—Henry Howson, Solicitor of Patents, and Charles Howson, Attorney-at-Law. Porter and Coates, Philadelphia. 16mo., 164 pp.

This brief treatise of the law of patents, as established by legal decisions, is, notwithstanding its brevity, exceedingly thorough and full in all the bearings of the law upon the issuance, maintenance, and traffic in patents. Passing over the opinions set forth in the introductory chapter, where, although the statements of fact are beyond question, the conclusions therefrom express only the views of the writers, the succeeding chapters give the words of the statute, with explanatory comments based upon copious references to cases which have been adjudicated. It is as clearly and distinctly set forth, as the use and meaning of legal language will admit—to *whom* patents are granted, and to whom they are not granted; weighing all the possible conditions of individuals and of grants—for *what* patents are granted, and for what they are not granted; covering all subjects of invention, whether process, material, or principle, combination or improvement—how to obtain a patent, and what will prevent this purpose; giving all the forms and courses of procedure which will or can arise in the Patent office and Courts in the attempt to procure a patent—and completing the treatise by a consideration of interferences, re-issues, assignments, grants, licenses, infringements, etc. An excellent and copious index adds to the value of the book immensely. It is fair to state that many of the quoted decisions have not met the scrutiny of an appeal to the Supreme Court, and that some others which are quoted have been based upon a somewhat different statement of the case than they have been applied to in the text of this book, and some of them would properly be overruled by the first clear-headed judge; but all this belongs to the well-known uncertainty of the law. In any event this little book supplies a popular as well as a legal want in the knowledge of the operation of the patent laws, and is worthy of a place on the shelves of all lawyers, and should be owned by all who intelligently, for themselves, wish to become patentees; or who, being now patentees, desire to appreciate the rights and uncertainties of their property.

PRACTICAL TREATISE ON THE CONSTRUCTION OF IRON HIGHWAY BRIDGES. Alfred P. Boller, C.E. John Wiley & Sons, N. Y. For sale by Claxton, Remsen & Haffelfinger, Phila.

This unpretentious treatise is scarcely popular enough for the most general reader, but it is sufficiently so to answer the purpose of instruction to any interested one. To the town or country officer who

is called upon in any way to consider what are the requisites of bridge building, it cannot fail to impart a flood of the most useful information. There have been no failures so hopeless as those which have been made by the uneducated practical man in the erection of roofs and bridges when they have relied upon and been trusted for their own ingenuity and observations, with guesses of strength in place of computations. This book should be put in the hands of those who have the authorization of expenditures for bridges, and it would lead them to see for themselves that while the construction of a bridge is not only limited to a few practical styles which they can readily understand; the absolute requirements of strength of parts need the estimate of the engineer, as decidedly as in making a purchase or sale, the weighing of hay or measuring of wood is a necessity of trade. The work will go further in the hands of the local surveyor or district engineer than any treatise on bridge construction before written to satisfy him that special information and experienced practical knowledge in bridge engineering is essential in reconciling the antagonistic bids and claims of rival proposers, and lead him to seek professional assistance to share his responsibilities, and in this way alone it is a most valuable addition to our technical literature.

Proposed Continuation of the Experiments of the late Prof. Walt. R. Johnson on American Coals.—The National Academy of Science has prepared a memorial to Congress, asking for a continuation of these extremely valuable experiments, to be extended to the coals of the Mississippi, and those of the elevated country beyond, to the Pacific Coast. The principal plea of this memorial is in behalf of the national protection and the demands of the U. S. army and navy, but the secondary one, in the interest of manufactures and commerce, would present a much stronger claim upon the government. Fuel is the primary necessity of modern civilization—the basis of modern industry, and the development of the resources of the country by investigation, under national direction and authority, is an unquestionable duty of Congress. No one of the numerous publications in the way of statistics ever made by the authority of the United States has had a larger quotation, or been more practically useful in the arts and sciences, than this original Report of Prof. Johnson, and an equally well considered document which should embrace the *fuel* and the *fuel* resources of this country would be appreciated in all lands. It is to be trusted that this recommendation of the academy will be liberally responded to.

Civil and Mechanical Engineering.

CONTINUOUS GIRDERS AND DRAW SPANS.

By A. Jay DuBois, C. E., Ph. D., Prof. Civil and Mechanical Engineering, Lehigh University, Bethlehem, Pa.

In a very excellent and justly popular "Engineer's Pocket Book," (John C. Trautwine, the Civil Engineer's Pocket Book, 1872, p. 304), our attention has lately been called to the remark that "the strains upon a drawbridge are very complicated; and the designing and construction of such bridges when of large spans, should be entrusted to experts only." In Humber's "Strains in Girders," (New York, D. Van Nostrand, 1869), we also find the statement that "it would perhaps be impossible to give mathematically accurate formulæ for the moments of rupture in continuous beams with moving loads, that would be worth anything for practical application." This statement is supported by reference to a "well known author" (J. H. Latham, "Iron Bridges"), who has even pronounced the case "too complicated for investigation." The graphic constructions given by Humber in the work above alluded to, are themselves only applicable upon the supposition that the spans are so proportioned, that the moments at any pier due to two successive loaded spans are equal; a condition which cannot certainly be realized for moving loads. Again, in a more recent publication ("Graphical Method for the Analysis of Bridge Trusses," Greene, New York, D. Van Nostrand, 1875), we find that "the mathematical investigations are intricate, and the formulæ deduced troublesome in application," that "a partial solution of the problem by mathematical calculation is attended with considerable difficulty, and that a complete solution for the bending moments and shearing forces at every section under moving, partial and irregular loads, tasks the powers of the best mathematicians, and is well nigh impossible, on account of the complexity of the formulæ, so far as any practical application of them by the engineer is concerned."

Again, in a work entitled "Strength of Beams, Columns and Arches," by B. Baker, E. & F. N. Spon, 1870, we read on page 313,

"the determination of the exact mathematical value of the maximum strains occurring in continuous girders of three or more spans, when subject to a moving load, involves problems of almost hopeless intricacy. The most expert mathematicians would have to devote a month or more to the preliminary calculations for a very ordinary bridge, and the results deduced, would not, after all, be more reliable in practice than those arrived at by comparatively simple modes of investigation . . ."

The above remarks and quotations illustrate well the prevailing opinions upon this subject in England and this country, and with these opinions we venture to join issue at every point. The problem of the continuous girder, including of course the particular case of the draw span, is not only capable of "complete solution," but *has been solved* both graphically and analytically with a thoroughness and precision which leaves, at least in a practical point of view, nothing to be desired.

Clapeyron's famous "theorem of three moments" (1857) was long since extended by *Bresse*, *Winkler*, and others (1862), to single concentrated loads in any position. *Culmann* and *Mohr* (1866) have given us a complete graphical solution, and in the latest work of *Winkler* ("Theorie der Brücken," Wien, 1873), we find both solutions given side by side, while in the recent work of *Weyrauch*, ("Theorie der Trager," Leipzig, 1873), a book well worthy to close the long list of investigations upon the subject, we find a most complete and extended discussion and solution. Finally, in the pages of this magazine for March and April, 1875, will be found formulæ deduced by Mr. Merriman, of the Sheffield Scien. School of Yale College, than which, nothing more simple or comprehensive can be desired by the practical engineer and constructor.

It is not our purpose to give a history of the subject, or we might perhaps show that it is little to the credit of English or American authors that they have so long treated it with "judicious silence," and thus ignored one of the most important developments of the last decade in engineering practice. The importance of the theory of the continuous girder as applied to *draw spans*, will at least be generally admitted; and when our engineers shall have become convinced of the fact which has already been demonstrated and admitted by German engineers, that there is a saving of material in the continuous girder, *casteris paribus*, of from 25 to 30 per cent. usually, and even

reaching as high as, in extreme cases, 50 *per cent.*, it is possible that even the continuous girder itself may meet with more favor than at present. The objections of such, and they are not few, who are ready to assert that this saving is imaginary, are best met by referring them to the theory, which is at the bottom precisely the same as that which they accept and work with, in the case of the *common* girder. If its results are accepted in the latter case, as they are universally; if the simple girder comes out merely as a particular case of the more general continuous girder; they must either reform their own practice or accept the conclusion. There are others, and they also are not few, who not denying the "theoretical result," hold that it cannot be realized "in practice." To such, the questions seem pertinent, 1st, how do you know? Have you ever tried? 2d, do you know of those who have tried the question and decided it adversely? If the first questions fail to meet a response, the whole case turns on the second. If that also is unanswered, the whole subject remains open most certainly. In this country the first question must remain unanswered. In the work of Winkler, above referred to, however, may be found a list of nearly a hundred continuous girders *actually erected* in Spain, England, Austria, Prussia, Switzerland, France, Italy, etc., of all spans, from 500 feet down, and all numbers of spans, from six down. Now the decision of those who *have* thus fairly tested the question is favorable, and the construction of such girders still goes on. Would it not be well then for those who boldly deny the possibility of such constructions, or their advantages, either theoretically or practically, to first inform themselves upon the theory they thus condemn, and the practice they thus oppose? Should theory alone indicate an advantage which in practice is only imperfectly realized, it ought, one would suppose, to be, if anything, an incentive to a nation not generally considered as deficient in inventive genius, and whose record, especially in bridge construction, during its early stages, is still an example of what may be done with imperfect materials, to obtain in practice the gain which theory indicates. At least, one would suppose that when others have successfully met the difficulty, such a nation would not be found very far behind. At present, it stands as a fact, that in nearly every civilized country, America excepted, the continuous girder has been investigated, erected, tried, and accepted, while American engineers still wisely shake their heads, doubt, and decline to try.

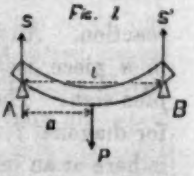
The influence of the work of *Weyrauch*, above quoted, is already to be seen in this country in the treatise by *Clemens Herschel* upon "Continuous Revolving Draw Bridges," (Boston, Little, Brown & Co., 1875). Finally, in this JOURNAL, for March and April, we may notice an article upon continuous girders by *Mansfield Merriman*, giving formulæ of the highest importance for the practical solution of the problem. Merriman's formulæ apply to any number of spans of any lengths, for uniform load over any single span, or for single concentrated load in any one span, and are so compact that everything necessary for the complete solution of the continuous girder may be entered upon a couple of pages of the note book. The calculation then proceeds in a manner precisely similar to that for the simple girder; which last is indeed but a particular case of the more general formulæ.

As to the difficulty of solution: if ability to calculate a continuous girder or draw span constitutes an "expert," we venture to hope that the perusal of these pages will put the reader in full possession of such a desirable accomplishment.

We shall first indicate the general nature of the problem required to be solved; what quantities are unknown and must be found, and how these quantities are then made use of. We shall then give a concrete example illustrating the above, assuming that we know what the desired quantities are; and, lastly, we shall give the formulæ of Mr. Merriman, by which these desired quantities may themselves be found. A few remarks upon the relative advantages and disadvantages of the continuous girder will then close our discussion.

II.—General Nature of the Problem.

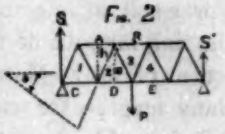
If a girder simply rests at its two ends upon supports, and is acted upon by any weight or weights, as in Fig. 1, we know that the weight P causes "*reactions*" at the ends, that is a *shear* S just to the right of the left support, and a shear S' just to left of right support. Now, these forces, viz., the weight and the end "reactions," are *all* the outer forces which act upon the girder. These outer forces being necessarily in equilibrium, because otherwise there would be motion, we can find S and S' by moments about A and B, or by the "law of the lever." Thus, if a is the distance of weight P from left end, and l is the length of beam, we



have, by the "law of the lever," $S \times l = P\,(l - a)$, and $S' \times l = P\,a$ or $S = \frac{P(l-a)}{l}$ and $S' = \frac{Pa}{l}$. Now, in any framed structure whatever, when once *all* the outer forces are known, the strain in any and every piece can easily be found by moments.

Thus, Fig. 2: let the height of truss be h, and panel length $\frac{l}{4}$, or one-fourth of the entire length. Now, we can find the strain in *any* piece whatever, by supposing the structure cut entirely through by a plane which cuts only three pieces, the strains in which are unknown, and in order to determine the strain in any one of these pieces, *take the intersection of the other two* as a centre of moments. Thus, suppose A, 2 and D cut. Then, to determine A, take the centre of moments at the intersection of 2 and D, the other two pieces. We have then str. in $A \times h = S \times \frac{l}{4}$ or str. in $A = \frac{Sl}{4h}$. Again, str. in $D \times h = -S \times \frac{3}{2}\,l$, or str. in $D = \frac{3\,Sl}{8\,h}$, tension being considered minus, and compression plus, and rotation, which would cause tension, being minus; and so on, for any flange, not forgetting to take into account the weight P when we pass it. Thus, str. in $E \times h = -S \times \frac{3}{2}\,l + P \times \frac{1}{2}\,l = -\frac{5\,l\,S}{8} + \frac{Pl}{8}$; or str. in $E = \frac{P\,l - 5\,l\,S}{8\,h}$, the centre of moments being always at the intersection of the *other two pieces* cut, viz. here, 4 and B; or, what is the same thing, we may take str. in $E \times h = -S' \times \frac{3}{2}\,l$, or str. in $E = \frac{3\,l\,S'}{8}$, thus leaving out P by taking the other reaction. Any single moment which tends by itself to cause tension in a piece, may be put down with minus sign, if compression, with plus sign. The method is precisely the same for a diagonal. Thus, for diagonal 2, the intersection of *the other two pieces*, viz., A and D, is here at an infinite distance, since A and D are parallel.* Taking

Fig. 2



* If A and D are not parallel, their intersection is the centre of moments for the diagonal, with reference to which the moments of 2 and S must balance, just as above, for the infinitely distant point.

this point, then, as a centre of moments, we have, since the lever arm of 2 is $\infty \cos \theta$, where θ is the angle which the diagonal makes with the vertical; $S \times \infty =$ str. in $2 \times \infty \cos \theta$, or str. in $2 = \frac{\infty S}{\infty \cos \theta} = S \sec. \theta$, since $\frac{1}{\cos} =$ sec. and ∞ cancels out. Hence, the well known rule for parallel flanges, "multiply the shear by the secant of the angle which the diagonal makes with the vertical." If the diagonal were on the other side of the weight, we should have S' sec. θ or $(P—S)$ sec. θ. That is, the *shear is always the algebraic sum of all the forces between the point considered and the end.* If it acts up at the foot of a diagonal, or down at the top, it causes compression, otherwise tension. Thus, we see that all we need to know in order to calculate completely the strains in every piece, due to each and every weight, are the *outer forces.* These once known, the problem is one of simple multiplication. Such are, in brief, the principles by which we may calculate any simple truss of single span. Now, for a *continuous girder*, the principles are precisely the same, and their application precisely the same, and no more difficult, *provided that in this case also we know all the outer forces.*

Let us, therefore, consider what *are* in this case the outer forces; and how does this case then differ from the preceding.

If Fig. 3 represents one span of a continuous girder, which sustains a weight P at a distance a from the left end, we have, just as in Fig. 1, of course, two reactions or *shears* S and S' at the supports, which are, in general, different numerically from those obtained in the first case, and *in addition* at each end a *pair* of forces, *or couple* acting to cause tension in the upper fibre and compression in the lower at the supports. Owing to this couple, we have then at the supports not only the shears, S and S', *but also two moments*, M and M'. These moments we always consider positive when tending, as in the figure, to cause compression in *lower flange*, or fibre, otherwise negative. That is, we take the *lower* flange as a flange of reference, and consider compression as plus and tension as minus. These moments, then, divided by the depth of the truss, or the lever arm of the forces, will, of course, give the intensities of the forces themselves, acting in the upper and lower flanges. If the moment is positive, these forces

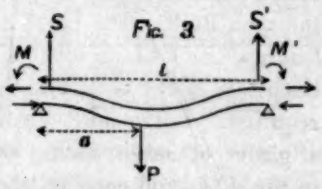
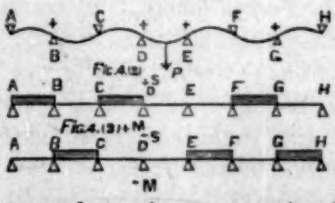


Fig. 3

act as shown in Fig. 3, so as to cause compression in lower flange at supports and tension in upper. If the moments are negative, these forces are respectively reversed in direction, so as to cause tension in lower flange at supports and compression in upper. The shears are positive if acting upwards, negative downwards. Now, these are *all* the outer forces acting upon the truss, and *if we can only find what they are*, precisely the same principles which held good for Fig. 2, hold good here also, and no more difficulty need be experienced for the one case than for the other. So far as loads in any one span are concerned, then, we simply have to find, and it suffices to know, what are the shears and moments due to a single load placed anywhere in that span. If we know them, we can easily find by moments the strains in every piece due to each apex load, and a tabulation of these will then give us at once the strains due to uniform dead load, and to moving load. Formulæ, then, which enable us to find the above quantities by simple insertion of the numerical values for any particular case, are all that we need for a load in any one span. Such formulæ we shall give hereafter.

But these do not solve the *whole* case. Loads *exterior* to any one given span, *i.e.*, situated in *other* spans, have also an influence and cause strains in the pieces of the span, the strains in whose pieces are required. The above formulæ, then, would only enable us to find the strains due to what we may call "*interior loading*," or loads in the span itself. We have now to consider the effect of "*exterior loading*," or loads in other spans, and the influence they have upon the pieces in the particular span, the maximum strains in which are required. Let us take, for instance, a girder of seven spans, as shown in Fig. 4 (1), and consider the action of a load in *D E*, the middle span.

Fig. 4 (1)



Now we easily see at once, that *both the moments and shears at the two supports of any loaded span must always be positive*, that is, there must always be compression in lower flanges, just over the end supports, and the shears there must act up, or opposed to the load. Now, if no other span is loaded, and if all the supports are on level, and the girder must touch every support, it must take a wavy line, such as shown in the Fig., and supports *C* and *F* must be above, *B* and *G* below, *A* and *H* again above

the girder. In general, then, *the moments and shears at the two ends of any loaded span are always positive; right and left from these two ends they alternate in sign.*

Now let us apply these principles to the span *D E*, the maximum strains in the pieces of which are required. First, considering each apex load in the span *D E* itself, that is the "*interior loading*" of the span, we are supposed from our formulæ to have first found the shear and moment (both positive) at the support *D* for each individual apex load. We can then, by the method referred to, in connection with Fig. 2, find the strains in each piece due to each of these weights, and tabulate them. We now come to consider "*exterior loading.*" For this purpose we wish, first, the greatest *positive* moment and shear at the same support *D*, due to exterior loads alone; and, second, the greatest *negative* moment and shear at *D*, due to exterior loads alone. We must find and tabulate the strains due to these two cases also by themselves, and the span is solved. Now, from our principles above, for these two cases, we reason as follows. Every load in *A B*, Fig. 4 (2), causes positive moments and shears at *A* and *B*, and then at the other supports the moment and shear alternate in sign. Thus, a *full* load over *A B*, as shown in Fig. 4 (2), gives a positive moment and shear at *B* and *D*. A load over *B C* gives a negative moment and shear at *D*; over *C D*, positive again at *D*. We skip the span *D E* itself—the "interior loading" applies to that—and go on to *E F*, a load over which gives negative moment at D, while over *F G* we have positive, and over *G H* negative moments, and shears at *D*. The case of loading represented in Fig. 4 (2), then, in which *A B*, *C D*, and *F G*, are fully loaded and the others unloaded, will give the greatest positive moment and shear which can possibly occur at *D* for exterior loading, and hence the greatest strains; while the case represented in Fig. 4 (3) gives the maximum negative moment and shear at *D*, and hence the greatest strains for that case. We must now find and tabulate the strains for these *three* cases, viz., "interior loading" strains, and the two cases of "exterior loading" strains. Now, if we know the *ratio* of dead to live load, then, by adding algebraically the strains thus found, and multiplying by this ratio the algebraic sum, we have a column for *dead load over the whole girder, from end to end.* We can now easily pick out the maximum strains which can ever occur, and determine what pieces must be counterbraced, and how much the strains are in each case.

In order to do all this, it will be observed that the *method* is precisely the same as for a girder of single span, and its application, though perhaps a little longer, no more difficult. We only need to know the outer forces. With these we work.

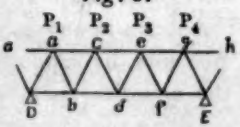
We see therefore at once what it is that our formulæ *must* do, and all that is necessary that they *should* do. They should enable us to determine for any number of spans of any lengths over level supports, first, the moment and shear at the end of any given span for a single weight placed anywhere *in that span*, second, the moment and shear at the end of that span for a uniform load over the whole of *any other span*. This is just what our formulæ, which we shall give hereafter, enable us to do, and although they also enable us to solve many other questions connected with the continuous girder incidentally, such as deflection, points of inflection, etc., the above is all that it is essential that we should know for full and accurate solution.

Before giving these formulæ, we shall now give briefly an example, illustrating the above, supposing that the moments and shears as found by the formulæ are known.

III. CONTINUOUS GIRDER.—EXAMPLE.

Let us take for example a girder of seven equal spans, and seek the maximum strains which can ever occur in the middle span *D E*, Fig. 5.

Fig. 5.



Let the length be 80 ft., divided into 4 panels of 20 ft. each, and let the live load be 2 tons per ft. or 40 tons at each upper apex, the uniform dead load being only ½ as much, or 20 tons per upper apex. Height of truss, 10 ft.

Now the quantities, which for the present we must suppose known, and which are given by our formulæ, are as follows :

Positive moment at *D* [1st system of exterior loading, Fig. 4 (2)], = + 788·2 ft. tons, corresponding shear at right of *D* = + 14·63 tons.

Negative moment at *D* [2d system of exterior loading, Fig 4 (3)], = —382·54 ft. tons, corresponding shear = — 14·63 tons.

Also for the interior loads in the span itself, we have :

For the first load P_1, moment at *D* = + 158·92, shear = + 36·17
" " second " P_2, " = + 271·96, " = + 25·88
" " third " P_3, " = + 203·36, " = + 14·16
" " fourth " P_4, " = + 62·88, " = + 3·82

These are all the data, which we need to know. The calculation now proceeds just as for a simple girder.

Thus the strain in the first end flange, *a a*, above *D*, is equal to the moment at *D* divided by height of truss. If the moment is positive it indicates compression in lower or tension in upper flange. Thus for first case of exterior loading we have in this flange $\frac{788\cdot2}{10}$ = 78·8 tension, since the flange is here an upper one. For the second case of exterior loading $\frac{382\cdot54}{10}$ = 38·2 tons compression. For interior loading, we have for P_1, 15·8 tons tension, and for P_2, 27·2, for P_3, 20·4, and for P_4, 6·4 tons, all tension likewise. In the first case of exterior loading also, the moment at $D = + 788\cdot2$, and the shear $S = + 14\cdot63$, cause strains in all the other pieces, which we can readily calculate. Thus, for instance, for this first case,

str. in $c\,e \times 10 = - 788\cdot2 + 14\cdot63 \times 40$ or str. in $c\,e = -$ 20·3 tons, the centre of moments being at *d*, and tension being minus, also

str. in $d\,f \times 10 = + 788\cdot2 - 14\cdot63 \times 50$ or str. in $d\,f = +$ 5·6 tons, the centre of moments being at *e*. A positive moment always gives compression in lower flange, tension in upper. Again, str. in diagonal $D\,a = S \times \sec. 45° = + 14\cdot63 \times 1\cdot414 = + 20\cdot7$ tons.

$a\,b = - 20\cdot7$, $b\,c = + 20\cdot7$, and so on alternating in sign, a positive shear acting up, and causing compression when acting up at the foot or down at the top of a diagonal.

The strain in any flange is thus easily obtained by a simple equation of moments, by supposing that flange cut and the point of rotation at the opposite apex, or intersection of the other two pieces, and then taking the moments of all the outer forces to the left of the section about this point, and finding the force which must act in the cut flange, in order to prevent rotation. For fuller explanation of this method of moments, see the author's "Elements of Graphical Statics," Wiley and Sons, New York; also his article in the April number of this JOURNAL upon the "Graphical and Analytical Determination of Strains in a Roof Truss."

In similar manner we can find the strains in every piece, due to the second case of exterior loading. Thus,

str. in $c\,e \times 10 = + 382\cdot54 - 14\cdot63 \times 40$ or str. in $c\,e = -20\cdot3$ tons

str. in $d\,f \times 10 = - 382\cdot54 + 14\cdot63 \times 50$ or str. in $d\,f = + 34\cdot9$ tons

str. in diagonal $D\,a = - 14\cdot63 \times 1\cdot414 = -20\cdot7$ tons.

$a\,b = + 20\cdot7$ $b\,c = - 20\cdot7$, etc.

So also in precisely similar manner, for each *interior* weight P_1, P_2, etc., we can find the strains. Thus take for instance P_1. For this weight we have the moment at $D = + 158{\cdot}92$, and shear $= + 36{\cdot}17$. Then the strain in first end flange $a\,a$, above D, is $-\frac{158{\cdot}92}{10} = -15{\cdot}8$ tons (tension is always *minus*), and str. in $D\,b \times 10 = + 158{\cdot}92 - 36{\cdot}17 \times 10$ or $D\,b = -20{\cdot}3$ tons; str. in $a\,c \times 10 = -158{\cdot}92 + 36{\cdot}17 \times 20 - P_1 \times 10$, or since $P_1 = 40$ tons, str. in $a\,c = + 16{\cdot}4$ tons. Observe that for this piece the weight P_1, also comes into the equation. Again, str. in $b\,d \times 10 = + 158{\cdot}92 - 36{\cdot}17 \times 30 + P_1 \times 20$ or $b\,d = -12{\cdot}6$ tons, and so on for every flange. For the diagonals, str. in $D\,a = S \times$ sec. $45° = 36{\cdot}17 \times 1{\cdot}414 = + 51$ tons. For diagonal $a\,b$, by reason of the weight $P_1 = 40$ which acts down at a, the shear is $-40 + 36{\cdot}17 = -3{\cdot}83$ tons, which, since the weight preponderates, acts down, and hence causes compression on $a\,b$ also, of $3{\cdot}83 \times 1{\cdot}414 = + 5{\cdot}41$ tons, $b\,c = - 5{\cdot}4$, $c\,d = + 5{\cdot}4$, and so on alternately plus and minus for the rest. Thus we proceed for each weight, and can thus fill out the following table.

1	2	3	4	5	6	7	8	9	10	11	12
Flanges.	Interior loads.				Interior loading. Maximum strains.		Exterior loading.		Dead load = ½ live.	Total maximum strains.	
	P_1	P_2	P_3	P_4	Tens. −	Comp. +	1st Case.	2d Case.		Tens. −	Comp +
$a\,a$	−15·6	−27·2	−20·4	−6·4	−69·6	.....	−78·8	+38·2	−55·1	203·5	....
$a\,c$	+16·4	+24·4	+8·0	+1·2	.....	+50·0	−49·5	+8·9	+4·7	44·8	63·6
$c\,e$	+8·8	+36·4	+36·4	+8·8	.....	+90·4	−20·3	−20·3	+24·9	15·7	115·3
$e\,g$	+1·2	+8·0	+24·4	+16·4	.....	+50·0	+8·9	−49·5	+4·7	44·8	63·6
$g\,h$	−6·4	−20·4	−27·2	−15·6	−69·6	.....	+38·2	−78·8	−55·1	203·5	.....
$D\,b$	−20·4	+1·2	+6·0	+2·8	−20·4	+10·0	+64·2	−23·6	+15·1	28·9	89·3
$b\,d$	−12·8	−50·8	−22·0	−5·2	−90·8	.....	+34·9	+5·6	−25·1	115·9	15·4
$d\,f$	−5·2	−22·0	−50·8	−12·8	−90·8	.....	+5·6	+34·9	−25·1	115·9	15·4
$f\,E$	+2·8	+6·0	+1·2	−20·4	−20·4	+10·0	−23·6	+64·2	+15·1	28·9	89·3

We give in the table, in order to economize space, only the flanges; the method is precisely the same for diagonals also, but for the purpose of illustration a few of our results are sufficient.

Having found, and tabulated the strains due to each weight, as shown by the first 5 columns for interior loading, we add all the tensions and compressions for each piece, and place the results in columns 6 and 7. We thus have the "maximum strains" which can be caused by the interior loads alone in the span *D E*. In the next two columns, 8 and 9, we now place the strains due to the two cases of "exterior loading" [Fig. 4 (2) and (3)]. Now if the uniform dead load is known to be any ratio of the live, as say $\frac{1}{2}$, we have only to take the algebraic sum of the strains in columns 6, 7, 8, and 9, horizontally, and put one-half this sum in column 10. We thus find column 10 for dead load. Finally, from columns 6, 7, 8, 9, and 10, we can find the *total maximum strains*, which can possibly occur, as given in the last two columns, 11 and 12. Thus, take for instance, the piece *a c*. In this flange there is a constant compression due to the dead load of 4·7 tons. The second system of loading, if it should ever occur, which, if not probable, is at least possible, would add to this, 8·9 tons, while interior loading may at the same time independently cause 50 tons, all compression. Since all three cases *may* exist together, we have $4{\cdot}7 + 8{\cdot}9 + 50 = 63{\cdot}6$ tons compression in *a c*. But again, the *first* system of exterior loading, which may also act alone, causes 49·5 tons tension in *a c*. Diminishing this by 4·7 tons compression, due to dead load, which must always act, we have $-49{\cdot}5 + 4{\cdot}7 = -44{\cdot}8$ tons tension in *a c*. These two strains are the greatest which can ever occur in this piece. We see also that this piece must be counterbraced, because the tension — 49·5 for first case, is *greater* than the constant compression of 4·7 due to dead load, while on the other hand *g h* need not be counterbraced, because the greatest compression which can ever occur, viz., 38·2, is *less* than the constant tension 55·1 due to dead load. So also for *a a*. Since in this case we have taken a middle span, observe that the strains for P_1 and P_4, P_3 and P_2, are similar, as they should be. Thus, strain in *a a* due to P_4 is the same as in *g h* due to P_1, and so on.

Thus we see that the method of calculation is precisely the same as for a girder of single span. In this latter case, columns 8 and 9 would of course fall out; also, since there are no end moments, and

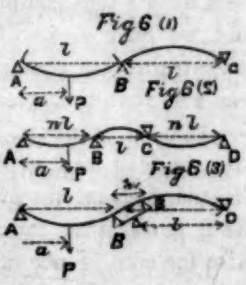
since the end shears are different, the numerical values of the strains in columns 2 to 5 will be different.

In any framed structure whatever, then, it will be seen that the sole difficulty is in finding all the *outer forces* for any desired loading, and that generally the repetition of a single load covers all cases of moving, or live and dead load.

The outer forces, such as end moments and shears, being once known, the rest is easy. In the author's work, entitled the "ELEMENTS OF GRAPHICAL STATICS," *Wiley and Sons*, New York, will be found many examples in illustration of the above, together with easy and practical methods of finding the outer forces for continuous girders, pivot spans, braced arches, suspension trusses, and all the various forms of girders and roof trusses, which occur in engineering practice, together with the methods of calculation and diagram.

IV. THE PIVOT OR DRAW SPAN.

The method of calculating the strains in a pivot span presents no difficulty, provided, as always, we know the shears at the supports for a weight anywhere. The pivot span may be considered as a girder, continuous over three supports, or in some cases, over four supports, the small intermediate span being the width of the turn table. In this latter case, again, it may happen that both the centre supports are pivoted upon a third, so that they can *tip* under the action of a weight, one down and the other up. In Fig. 6 we have these three cases. The two first are, of course, only particular cases of our general formulæ, which we shall give hereafter. The third was first noticed, and the formulæ for the "reactions" at supports first given by Clemens Herschel, (Continuous revolving draw spans, Little, Brown & Co, Boston). Of course, in any case, for an *end* support; "reaction" is the same as *shear*, since there is no other span beyond, to contribute its pressure to the support. But in general, at any support, the reaction is the *sum of the shears on each side*. They are shears which our formulæ give, and they should *never* be confounded with "reaction."



Now in the case of the pivot span, it is evident that if the shear at *A*, due to a weight placed anywhere in any span is known, then, since

at this support there is no end moment, we have all we need, in order to find the strains in every piece of the span *A B*. The strains in the other end span will, of course, be the same, if, as is nearly always the case, the two are of the same length; if not, they can be calculated for the second, as for the first. The middle span, if any, when it rests directly upon the turn table, can be disregarded; otherwise it is calculated precisely as for a span of a continuous girder, already illustrated.

The centre support should be *raised above the level of the ends by precisely the amount that the draw when open deflects;* otherwise, when once opened it would evidently be difficult to shut it again.

The dead load strains, then, are found for draw open, and these same strains exist unchanged, even when the draw is shut. The live loads only are to be considered, each by itself, for draw shut, and the fact that the centre support is thus raised, *will not affect the shears as given by our formulæ.* This fact was first pointed out by Clemens Herschel in his work above referred to, and the proof of it may be found in the author's "Graphical Statics." Moreover, it is not necessary to enter into elaborate computations, as to the precise amount by which the centre support must be thus raised; it is only necessary in practice, to raise the centre support till the ends just bear and no more.

We have then two calculations to make, one for draw open and strains due to dead load; the other for draw shut and strains due to live load; the union of the two gives us the maximum strain in any piece. In order to make the latter calculations, we have simply to find the reaction (shear) at end support, for each and every apex load in all the spans (generally omitting centre span, which rests directly upon the turn table). Although the formulæ, which we need, therefore, are merely special cases of more general formulæ, which we shall presently give; still the case of the draw is so important that we shall give here the special formulæ required.

Let the load P be at a distance a from the left support A, then we have for *two equal spans*, $l = A\,B = B\,C$, Fig. 6, for the *reactions* at the supports A, B and C;

$$R_A = \frac{P}{4l^3}\,(4\,l^3 - 5\,l^2\,a + a^3).$$

$$R_B = \frac{P}{2l^3}\,(3\,l^2\,a - a^3).$$

$$R_c = \frac{P}{4l^3}(a^3 - l^2 a).$$

Remember, that the shear at *ends* is the same as reaction, but the middle "reaction" is the *sum* of the shears on each side of of the middle support. For load in other span we can use the same formulæ. Thus reaction at A for load in $B\ C$ is same as at C for similarly placed load in $A\ B$, etc. These reactions add up equal to the load P, as should be.

For the second case of four fixed supports, Fig. 6, we have for a load P in the left end span $A\ B$, at a distance a from the left support A, the *end* spans being $n\ l$ and the centre span $B\ C = l$, the following formulæ for reactions.

We put the ratio of the distance a to the length of span $n\ l$, or $\frac{a}{n\,l} = k$ and represent a quantity of frequent occurrence by H, viz. $H = 3 + 8\ n + 4\ n^2$. Then

$$R_A = \frac{P}{H}[H - (\mathrm{H} + 2\ n + 2\ n^2)\ k + (2\ n + 2\ n^2)\ k^2].$$

$$R_B = \frac{P}{H}[(3 + 10\ n + 9\ n^2 + 2\ n^3)\ k - (2\ n + 5\ n^2 + 2\ n^3)\ k^3].$$

$$R_C = \frac{P}{H}[-(n + 3\ n^2 + 2\ n^3)\ k + (n + 3\ n^2 + 2\ n^3)\ k^3].$$

$$R_D = \frac{P}{H}[n\ k - n\ k^3].$$

These reactions should add up equal to the weight. They are all we need, as loads in the centre span $B\ C$ can be disregarded, and in the right end span the same formulæ apply, only we have to put R_D in the place of R_A, R_C in place of R_B, etc., and take a from D towards the left, instead of from A towards the right.

For the third case, or the *tipper*, we take for the sake of distinction, the *middle* span, equal to $n\ l$, and the two outer ones each l. We have k then equal to $\frac{a}{l}$, and we now put $H = 4 + 8\ n + 3\ n^2$. The reactions are now therefore*

$$R_A = \frac{P}{2H}[2\ H - (10 + 15\ n + 3\ n^2)\ k + (2 + n)\ k^2].$$

$$R_B = R_D = \frac{P}{2H}[(6 + 9\ n + 3\ n^2)\ k - (2 + n)\ k^3].$$

* For demonstrations of these formulæ see author's Elements of Graphical Statics.

$$R_c = \frac{P}{2H}\left[(2+n)\,k^3 - (2+3\,n+3\,n^2)\,k\right].$$

These reactions when added together, $R_A + 2\,R_B + R_C$, are equal to P, as should be. By the application of these formulæ, which for any particular case are by no means intricate, we can find the reaction at A for every apex load, and can then calculate the strains in each piece of the span $A\,B$ for each and every load. A negative reaction in any case, indicates that the support must be above, and unless more than counterbalanced by the dead load, the girder will rise off the support if under, unless latched down.

The above comprises all that need be said under this head; we shall now give an example illustrative of the above, and then pass on to the general formulæ so often referred to, by means of which we can in any case, for any number of spans, find the moments and shears at any support.

(To be continued.)

GAS WORKS ENGINEERING.

By Robert Briggs, C.E.

[Continued from Vol. ci, page 301.]

"Most of the sulphur distilled from the coal passes over with the ammoniacal liquor, and the authorities vary considerably as to the quantity present in crude gas. But, taking the weight of a cubic foot of crude gas, at the temparature of sixty degrees Fahrenheit, with the density of fourteen-candle gas, as equalling two hundred and thirty grains, and two-tenths of one per cent. as the weight of sulphur, there would be four and six-tenths grains of sulphur per cubic foot; while the standard for excellence is (as has been stated, twenty grains per hundred feet) two-tenths grains per cubic foot; showing that only one twenty-third the sulphur which existed in crude gas, is tolerated in purified gas. When gas, either crude or purified, is burned, all the compounds are reorganized in the products of combustion; the sulphur compounds are decomposed, the sulphur itself going to form, with oxygen, sulphurous acid; the ammonia compounds resolve into nitrogen and hydrogen, the latter going to form,

with oxygen, water; but it is possible that a little nitric acid may form in the process of incomplete combustion. The sulphurous acid, also, probably transforms itself in the air into sulphuric acid. At all events, the effect of sulphur in gas, even when reduced to very small amounts, approximating in quantity to the standard accepted by English law, is very perceptible upon colors of fabrics, paints, leather, etc., and especially perceptible to the occupants of rooms in which many burners are used. A sensation, not so much of smell, but of dryness and acridity in the nostrils and throat, accompanied with a binding feeling in the forehead, is recognized as the indication of bad gas; and immediately complaint follows when imperfect purification has occurred.

"In the history of the manufacture of gas, it appears that the earliest difficulty encountered was this defect of crude gas; and the necessity of removal of sulphur at once engaged the attention of the first gas-makers. These gas-makers were not chemists, and the science of chemistry had scarcely then, in 1800–10, reached the point to designate what was required to effect the purpose,—it was consequently a mere trial of various substances.

"Washing with water was first resorted to, and after a time lime-water was substituted in the hope that it might answer. The use of lime-water proved very satisfactory, and up to the present time no material of cheap or ready application has been found so efficient and satisfactory in result, although it will be seen that it has some troubles in the disposition of the spent lime-water, in the gas-works themselves, that have so far proved insuperable.

"The ammonium compounds, when present in gas, are less harmful to the consumer, but they destroy the grease of the gas-cocks, injure the burner-tips, rust away and eat up the material of gas-meters, occasion deposits of very offensive liquors which sometimes escape, and they impair materially the illuminating quality of the gas.

"The naphthaline passes off with the gas from the retort as a vapor (probably other hydro-carbons of nearly the same constitution accompany what the gas-maker knows as naphthaline). It is one of the few hydro-carbons which isolate themselves positively in the process of destructive distillation of coal, and at ordinary temperatures is seen as a fine white crystalline mass, in which form it condenses and deposits as the gas is cooled. Crude coal tar has a large quantity dissolved in its oils, which is separated by heat, between the light and heavy

oils. It is believed, however, that crude coal tar will absorb it all (or nearly all) if the tar is allowed to remain, and be brought in contact with the gas until quite cold; but as the tar also absorbs all the gaseous illuminants in this way, this process is not available. Naphthaline occasions stoppage of the pipes in cold weather, and is a source of great trouble to some gas-works, where the condensation is not slow enough to separate it. It is freely dissolved and absorbed by gaseous hydro-carbons (the luminant gases), and when it occurs in pipes can be removed by use of very *rich* gas for a time. It is a luminant itself, and can only be classed with the impurities, because it must be removed to certain limits of quantity (varying with certain seasons of the year) to admit of the service and distribution of gas.

"Naphthaline has a pungent, distinctive odor, which disseminates to great distances when any of the vapor is allowed to escape. It is probably the *vehicle* of other smells from coal gas, as musk is made to convey some perfumes. Naphthaline resembles camphor in many ways.

"The non-burning substances are not injurious, only that their presence in any proportion reduces the luminous efficiency of gas, to a far greater extent than is due to the quantity present. A very little air or carbonic acid will reduce the light of a fourteen-candle burner to that of seven candles. One per cent. of carbonic acid is said to impair the light five per cent., and six per cent. of air to impair it fifty per cent. The air accompanying any gas, comes from changing the purifiers at the works, and similar admissions; but carbonic acid is one of the products of distillation.

"Of all these compounds of the gas, but very few are positively poisonous. Sulphuretted hydrogen (mainly), and carbonic oxide (in a less degree), are the most abundant and dangerous by themselves. Some of the ammonium compounds would be equally noxious if they were isolated, and if sufficient quantities were dispersed in any locality; but, as before stated, complete combustion reduces all these products to comparative harmlessness.

"In the burning of a gas-flame, the burning substances appear to be employed in establishing such a heat as shall cause the particles of carbon in the luminants to become incandescent, and the light is assumed to proceed from these particles, which are intensely heated and isolated from oxygen (air), so that they do not burn at that instant; the further progress of combustion is the burning of these

particles, so that they will be made into carbonic acid, and not be disseminated as smoke. If the heat is not intense enough they may never become incandescent or luminous, but merely separate from their vehicle (the hydro-carbon), and pass off as smoke altogether.

["The chemical composition of purified gas, of 16 candles burning power, is nearly as follows, per hundred parts: Hydrogen, H_2 44 to 48; Marsh gas, C H_4 34 to 38; Olefiant gas, C_2 H_4 and other hydro-carbons, etc., 6 to 8; carbonic oxide C O, 5 to 7; carbonic acid C O_2, 1 to 3; air N_2 O, 1 to 3, aqueous vapor H_2 O (to saturation, 40° to 60°), 1 to 2. The specific gravity of coal gas of the assumed quality, that is, the weight of a given volume as compared to that of air at the same temperature and pressure is 0·430; and this gives the volume of a pound of gas at 70° to be 31·4 cubic feet, when the volume of a pound of air is 13·5 cubic feet (neglecting fractions, in both cases, too small to be of consequence for the purpose of the present estimates).

"Taking the average of the constituents of coal gas, they can be reduced to 53 parts of hydrogen, 34 parts of carbon, 6 parts of carbonic oxide, which are combustible; leaving 5 parts of non-combustible substances.

"For the burning of a cubic foot of gas there will be required all the oxygen which exists in two cubic feet of air; but in order to *effect* complete combustion, at least twice this volume of air must be provided, or must accompany the burning.

"When *a*, a burner of average size of 4½ cubic feet per hour will need 90 cubic feet of air in the same time, or 1½ cubic feet of air per minute.

"The gas in burning gives out a great quantity of heat, nearly 3½ times as much as proceeds from the burning of *the same weight of* coal in an ordinary fire; or, in other words, the 4½ feet burner will give out as much heat as a half pound of coal per hour on a grate.

"The theoretic quantity of heat proceeding from the burning of a pound of ordinary coal gas is 34,000 heat units (equivalent to one pound of water heated one degree Fah.), of which one half is radiant heat, and the other is taken up by, and exists in, the gases of combustion.]

"§ II. Having followed the chemical and physical phenomena of the production of illuminating coal gas from bituminous coal, the apparatus and manipulation can next be exhibited; and the works of

the Philadelphia Gas Trust, at Market Street station, can well be taken as a type of practice.

"I have visited these works, in company with others, for the purpose of observation and examination, and can describe with accuracy their construction and processes of working.

"The Market Street station of the Philadelphia gas works is situated on the river Schuylkill, the works themselves being west of Twenty-fourth Street, and between Chestnut and Market, and Market and Filbert Streets, where are located coal houses, retort houses, washer and condenser houses, purifying houses, lime kilns, and other similar buildings; and the station also includes a square, between Market and Filbert and Twenty-third and Twenty-fourth Streets, which square is occupied by holders, meter houses, offices, &c.

"The commencement of the operation is in the retort house.

"[§ § *One.*] The retorts are receptacles for the coal, in which it is enclosed to be heated. In the Philadelphia gas works retort house, they are long vessels of clay, measuring nine feet internally in length, and having a ⊐ section of twenty inches in width and twelve inches in height. The clay is two and a half or three inches thick, and increases in thickness to four inches, in a band around the mouth end, the back end being closed. This *kind* of retort is generally used in America; the section of twelve inches by twenty inches is very common, but thirteen inches by twenty-two inches, and even fifteen inches by twenty-four inches is sometimes used. The length is also, generally, almost universally, nine feet.

"In England, retorts are almost always circular in section, and eighteen inches to twenty inches diameter; and generally, but not universally, eighteen feet in length, and open at both ends. Some differences of climate—the extreme heat of our summers, and the extreme cold of our winters—make the closed retort preferable in this country, and the ⊐ retort is supposed to produce the larger quantity of gas from the coal by more perfect '*carbonization.*' Iron retorts of the same internal dimensions as the clay ones were formerly used. Although clay retorts were introduced before 1820 in Great Britain, yet their general adoption did not occur until about 1850, and their general use here was quite ten years later.

"The Philadelphia gas works continued the use of iron retorts longer than any other works in the world. Clay retorts require the use of '*exhausters*' (or pumps, which in this country are generally

rotary) to remove the gas as fast as formed, to produce a satisfactory yield or quantity of gas from the coal. Iron retorts are yet used for very small gas works, where not over four or five retorts are required to supply the quantity of gas needed.

"Retorts have a '*mouth-piece*' of iron, of the same shape as the retorts, attached by bolts to the mouth end. This mouth piece is about one foot long, and has both ends open, one to attach to the retort, and the other to be covered by a lid, which lid is held against it by a central screw; there being '*lugs*' (ears) on the sides of the mouth-piece, which carry a '*cotter-bar*' (cross-bar of iron) for the screw to go through. On the top or side of the mouth-piece is a '*bell*' (socket) for the stand-pipe.

"The retorts are placed horizontally in '*benches*' (nests) of five (six is as usual in large gas works; while one, two, or three are placed in smaller ones), and are built into an arch-way of fire-brick, nine and a half feet deep by about six and a half feet wide, and six or seven feet high, under the centre of the arch. The arrangement of retorts in the benches is two at the bottom, with a narrow fire-place three and a half or four feet long between them; two above, a little close together; and one in the middle on top. They are supported by the wall in front, and by 'blocks' of fire-brick in the middle and at the back end; so the heat from the fire will rise over them, to the top of the arch, and the gases of combustion will finally escape at the flue holes, which open into the chimneys in the back wall, the holes being below the bottom of the lowest retorts. The chimneys are ten or twelve feet high only. The iron mouth-pieces project and stand in front of the wall.

"The benches are placed in '*settings*,' or a number of benches or arches are contiguous; and the settings at the Philadelphia gas works, and in all large works, are placed back to back, making '*double settings*.' In the retort houses of the Philadelphia works at Market Street, there are six double settings of fifteen benches of fives (12″ by 20″ by 9′), or nine hundred retorts in all.

"The bench is heated to a clear white heat, and never allowed to cool while in service for the production of gas. The coal is brought in wagons of such size as will carry a '*charge*' for the five retorts, in readiness for charging them; and the process of continuous working is as follows:—The workmen first '*draw*' (discharge) the coke; commencing by loosening the cotter-bar screw, which breaks the

joint of the lid with the mouth-piece; they next light the gas, which begins to escape at the crack, and burn off all that will come out; then, removing the lids, the flame enters the retorts and frees them from gas on the inside; a hook of iron is now introduced, and the red-hot coke, just below incandescence, is drawn out upon the floor in front of the retort; where it is quenched with water, so that it will not continue to burn in a pile, and then shoveled up into a '*coke-barrow*,' and removed to the coke-heap. This operation is substantially the same in all gas works. Generally, perhaps, the hot coke is drawn into a wagon and removed to be cooled outside of the retort house, a procedure which greatly increases the orderliness of the house; and sometimes the whole retort house has a cellar beneath it, into which the coke is dropped to be quenched.

"I do not know of any other large gas works, except those of Philadelphia, where the coke is quenched in front of the retorts. At these works, the yard is open to the Schuylkill, and the coke heap exposed to public view from Market Street bridge, and it is probable that the quenching at the heap would be too demonstrative of steam and black dust to make it advisable to quench outside. As it is, the ventilators, along the roofs of the retort houses, are but very little above the level of Market Street, and very much below the level of the buildings adjacent to the gas works (within three hundred feet distance), many of which are dwellings; and consequently the steam from quenching, laden with coke dust, and charged with burned and unburned gases, escapes at the ventilators, and is swept, by any northerly wind, across Market Street; at times, nearly obscuring the way. The greater part of this nuisance would be avoided by the construction of a suitable coke house, with quenching apparatus, and a tower sufficiently high to condense the vapor and to carry off the gases above the buildings, where they could safely diffuse.

"In New York, at the several gas works which I examined last week in this regard, the quenching of coke is little better provided for; but as the works are all on a level with the streets and adjacent property, and as any one of the streets themselves is by no means the principal thoroughfare of the city, the nuisance is tolerable. At the Manhattan Works, in New York City (10th Avenue and West Eighteenth Street), the quenching is done out of doors, in an open yard, beside a wall that is twelve or fourteen feet high, on the line of West Seventeenth Street, which street is eighty feet wide and close to the North river, where the largest part of the travel is coal and dirt

carts. At the New York Gas Works (Avenue A and East Seventeenth Street), the quenching is done in the middle of the works, the coke being removed to a floor away from the retorts.

"The retorts having been emptied of the coke from the former charge, they are now filled by shovels with coal from the wagon. In most works they are filled by 'scoops,' or long, half-pipe vessels, which will contain either half charge (when two scoopfuls are used); or, with large scoops, holding the entire charge. The saving of time, the preservation of heat in the retorts consequently, and the proper distribution of coal in the retorts, is the result of scoop-feeding as compared with shoveling. Recently attempts have been made to substitute mechanical feeding and drawing for hand-work, but after eight years' trial in Great Britain, only a degree of success has been attained.

"The task will undoubtedly be accomplished at some not very far-off day; and at the New York Gas Works they have a retort house, nearly completed, with a locomotive mechanical '*charger.*'

"The charge for a twelve by twenty inch retort is, for four-hour charges, two hundred pounds of coal; for four hours and forty-eight minutes (or five charges in twenty-four hours), two hundred and forty pounds; but these quantities are exceeded by some, if not most, gas-works managers—not, however, beyond ten or fifteen per cent. The *charges* of retorts are called four-hour or five-hour (four hours forty eight minutes), to designate that so much time is allowed to work a *charge* of coal and replace the coke by another; that is, in the one case six repetitions of the operation are made, and in the other five, in the course of twenty-four hours. At the Philadelphia Works, an entire bench of five retorts is open at once, and this practice is usual in gas-works in the United States; but in England only a single retort (a through-retort) in any bench, is drawn at once. As there are fifteen benches on each side of each setting at the Philadelphia Works, the same workmen will draw from bench to bench, one after another, so that the operation of drawing retorts becomes pratically continuous for, perhaps, half of every hour of the time during the day and night; the intervals being only those demanded by the endurance of the workmen at such hot and severe labor.

"Having removed the coke and inserted the charge, the lids are closed, the joint being made by a 'luting' of clay and spent-lime, spread upon the edge of a cold lid, ready to replace the hot one, and

the cotter-bar screw completes the operation of the '*stoker.*' Lids without clay joints, in various forms, have recently come into use, with much saving of time and leakage; and one of these is being introduced at the Philadelphia Works.

"The enclosed coal rapidly acquires the heat of the retort; at first the products of distillation, are the vapor of water (steam) and oily hydro-carbons not very completely decomposed; afterwards the gaseous substances separate; and, after three and a half, to four and a half hours, little, except pure hydrogen, passes over. These volatile products pass out through the "stand-pipes," which are six or seven inches in diameter and eight to twelve feet high, being socketed to the mouth-pieces. At the top of the stand-pipes are '*bridge-pipes*,' which are U shape, one leg joined to the stand-pipe and the other joined to, and entering into the 'hydraulic main.'

(To be continued.)

SPEED OF SCREW STEAMSHIPS AND THE SCREW AS A PROPELLING INSTRUMENT.

By JOHN LOWE, of the U. S. Naval Engineers.

In all modes heretofore adopted for measuring the relations between the speed and power of screw steamships, the hull itself has been made the basis of the calculations, or in other words, the power required to propel a given hull at a given rate, has been sought for. Owing to the complex and often arbitrary shape of vessels, a satisfactory method of measurement is difficult of attainment, although numerous rules have been given for this purpose, none so good, however, as to exclude all others by its superior merits. Indeed, a "coefficient," which they all contain, is expressive of the difficulties experienced, and a confession of the defects involved. The more prominent of these rules are:

First, $W = \frac{S^3 B}{C}$ Boulton & Watt's.

Second, $W = \frac{D^{\frac{2}{3}} S^3}{C}$ Atherton.

Third, $W = G\,L\,\frac{(1+4\ sin^2\dot{a}+sin^4\dot{a})\,S^3}{20000}$ Rankine.

Fourth, $W = D^{\frac{2}{3}}\,(\cdot 1552\,S + \cdot 004684\,S^3)$ Greene.

In which W = indicated horse power,
S = speed in knots per hour,
B = immersed midship section of the vessel,
C = a coefficient,
D = displacement in tons of 2240 pounds,
L = length between perpendiculars,
G = mean girth of the immersed body,
$\dot{a}$ = angles at the points of inflection occurring in the immersed body.

In the first rule this coefficient varies from 800 to 150, in the second from 300 to 50. We must therefore choose from our precedents a coefficient suitable to our proposed vessel. In other words, we must guess at it, which is a truly remarkable way of arriving at a mathematical conclusion. The third rule supposes trochoidal lines, while the fourth, from its simplicity, and that its coefficients are constants, would seem to be the best one. Notwithstanding these and other rules it is a fact that numerous failures have taken place, due to some cause, of which the rules take no cognizance. The trouble is that these coefficients do not discriminate; but embrace the good and bad qualities of hull, machinery and propeller, in one inextricable and misleading confusion. Indeed, in many instances now afloat, vessels built from the same model, and with the same machinery, give very different results in the matter of speed. The inference is then unquestionably correct, that these differences are due to differences in the propelling instrument, and to no other cause, since none other exists. What is therefore required, is a rule discriminating more thoroughly, and which will enable us to improve in our practice. This it is proposed to do in this paper.

Instead of the hull, the favorite propelling instrument, viz., the screw, will be used as a basis for calculation, and no arbitrary coefficient will be introduced, but every step will be taken logically and every quantity distinct, enabling us to discriminate and to fix responsibility of failure where it belongs. It will presently appear that the diameter of the screw should be as large as practicable to obtain the best results. We then assume the other dimensions of the screw and

it remains to measure the power required to revolve it at a given rate. If the immersion of the screw is sufficient, the rules proposed give absolutely correct results, but if the immersion is insufficient, part air and part water will be displaced, and the power will vary, not with the cube of the revolutions, but in a lower ratio. In any case, however, the rule gives enough power, and unless these exceptions are greatly aggravated a very correct result is obtained. Now, although the theory herein involved is simplicity itself and easily understood, yet with singular perversity it is often as easily misunderstood. At the risk of prolixity every step from the elementary will therefore be considered. Attacking each difficulty singly, let us suppose our vessel fast to the wharf, the screw revolving, displacing the water. Underlying all work of this is the formula for accellerated motion, viz.: $v^2 = 2\,g\,h$. In which v = the space in feet through which an abstract body moves in one second of time. In other words, the velocity in feet per second h = the total space through which a body moves, the time being undetermined. $2\,g = 64{\cdot}4$ feet, the increment of gravity.

Now if a unit (one cubic foot) weighing γ pounds, falls h feet, it will perform and accumulate work to itself equal to $\gamma\,h$ foot pounds. If we would instantly stop this body, we must oppose a pressure equal to $\gamma\,h$ or more conveniently $\frac{v^2\gamma}{2g}$.

We therefore see how pressure is a function of the square of the velocity. If now this pressure, $\frac{v^2\gamma}{2g}$, thus supposed to be generated, is moved through a space h, it will perform work equal to $\frac{v^2\gamma\,h}{2\,g}$, which is true for all possible values of h. Now then, let h be such a space as can be accomplished in one second; the amount will then be $\frac{v^2\gamma\,v}{2g} = \frac{v^3\gamma}{2g}$, which is the work done in one second of time. This is an essential point to be clearly understood before proceeding.

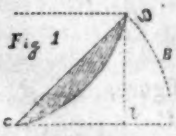


Figure 1 represents a plane, moving against salt water, in the direction b to c, at an angle $acb = \beta$, at the velocity v, in the direction b to c. The work done by this motion is as explained, equal to $\frac{v^3\gamma}{2g}$ into the dimensions of the plane, together with a coefficient due to the angle β.

That is, $dU = \frac{A v^3 \gamma \delta \, dx}{2g}$. (1)

In which dx = thickness or depth of the plane in feet,

$\gamma = 64{\cdot}125$, the weight of one cubic foot of salt water,

δ = the width $a\ b$ of the plane.

A, however, is the coefficient referred to as depending upon the angle B. Its value can be developed logically and is so developed in Weisbach's last edition. The length of the argument prevents its discussion here, however. Experimentally it was found by the writer by taking examples of propellers moving, the vessel being fast to the dock. The work of planes calculated by assuming each circular function was plotted at right angles to radius and integration performed by the planimeter.

The result thus obtained was then compared with the actual, and by this means the conclusion arrived at: That the sine is the proper measure of A. We have then,

$$dU = \frac{\sin \beta \, v^3 \delta \, dx \gamma}{2g}. \quad (2)$$

To make this equation of further use we must modify it so as to be applicable to the plane as situated in a screw.

For this purpose let n = number of blades in the screw.

x = position of the plane in radius or its distance from the axis in feet.

δ = length of the blade fore and aft the ship.

R = revolutions of the screw in one minute.

Then $\frac{R}{60}$ = Revolutions per second.

and $v = \frac{R\, 2\pi x}{60}$.

Therefore $dU = \frac{\sin \beta \, R^3 x^3 \, dx \, 8\pi^3 \delta \gamma n}{60^3 . 2g}$. (3)

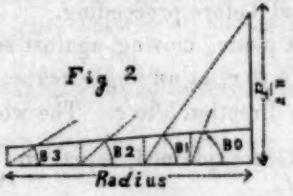


Fig 2

But by reference to Fig. (2). Sin β varies with $2\pi x$ and with the pitch P of the screw, or with x and $\frac{P}{2\pi}$.

Therefore, by the figure, sin $\beta = \frac{P}{2\pi\sqrt{x^2 + a^2}}$; a being $\frac{P}{2\pi}$. Substituting

this value of the sine we obtain:

$$dU = \left(\frac{x^3\,dx}{\sqrt{x^2+a^2}}\right)\frac{P R^3 2\pi^2 \delta \gamma n}{g.60^3}, \qquad (4)$$

which is the complete formula for one plane in each blade situated x feet from the axis. The total work done by the screw is the work done by each and every plane of which the screw consists. This summation is most easily done by integration of this formula. This operation is more simply performed by putting, $z^2 = (x^2 + a^2)$.

Then, $x^2 = (z^2 - a^2)$, $\frac{1}{z} = \frac{1}{\sqrt{x^2+a^2}}$ and $z\,dz = x\,dx$.

$$\text{Therefore } \int \frac{x^3\,dx}{\sqrt{x^2+a^2}} = \int (z^2 - a^2)\,\frac{1 z\,dz}{z}.$$

$$= \int (z^2 - a^2)\,dz.$$

$$= \left(\frac{z^3}{3} + a^2 z\right) + C.$$

Restoring the value of z; $\int \frac{x^3\,dx}{\sqrt{x^2+a^2}} = \left[\left(\frac{x^2+a^2}{3}\right) + a^2\right]\sqrt{x^2+a^2} + C.$

$$= \left(\frac{x^2 + 2a^2}{3}\right)(\sqrt{x^2+a^2} + C.$$

$$\text{or, } U = \left[\left(\frac{x^2 + 2a^2}{3}\right)\left(\sqrt{x^2+a^2}\right) + \frac{2a^3}{3}\right]\frac{P 2\pi^2 \delta \gamma n R^3}{9 \times 60^3}. \qquad (5)$$

In this expression V is the work done in foot pounds in one second of time which it will be remembered is not the fashionable mode of measurement. Sixty times U will be the work done in one minute, and this divided by 3300 pounds will give what is called horse power.

We have then as a final formula for the horse power required to turn the screw at the dock at the rate of R revolutions per minute,

$$W = [(x^2 - 2a^2)\,(\sqrt{x^2+a^2}) + 2a^3]\,\frac{P 2\pi^2 \delta \gamma n R^3}{3 g \times 60^2 \times 33000}. \qquad (6)$$

This is not a simple but is a correct formula in the light of numerous examples, ranging from the Tennessee to the Isherwood launch experiments.

Another formula, simpler in form but not otherwise so satisfactory, is to be obtained by regarding $\frac{PR}{60}$ as the velocity of the water displaced by the screw; by this is obtained

$$W = \frac{P^3 R^3 A \gamma n}{2g \times 60^2 \times 33000}. \qquad (7)$$

A being area of one blade of the screw athwartships. We have thus far considered the screw revolving at the dock; it remains to consider the effect of releasing the vessel.

There are two propositions involved, the truth of which we will prove experimentally.

First, when the vessel was at the dock, the water was displaced by the screw and not the vessel; but when the vessel was released the vessel was displaced and not the water. In the latter case, however, by its mobility the water yielded or "slipped," having the effect of making our common screw a Hunter or differential screw, there being a less displacement per revolution, or a greater number of revolutions to the same displacement and power.

The second proposition is: the resistance which causes slip is of two kinds, first, the resistance caused by the water to the vessel's progress. Second, the resistance of the wind, towing, etc., which may be either plus or minus. In order to compare the performances at the dock and under weigh it is necessary to reduce the revolutions to a standard rate, most conveniently one per minute.

Let $u = \frac{W}{R^3}$ = power at dock at the rate of one revolution per minute.

$u' = \frac{W}{R'^3}$ = power under weigh at the same rate.

Unity = water displaced by the screw at the dock in one minute.

$\triangle$ = relative displacement of the vessel under weigh in one minute.

c = displacement of water caused by external resistances, such as wind.

Then by the propositions $\frac{u'}{u} = \frac{(\triangle \pm c)^3}{1}$. That is to say the work at the dock and under weigh are in the same ratio with the displacements.

Inserting these in (6) and (7), we obtain equations embracing all possible conditions.

Viz.: $$W = [(x^2 - 2a^2)(\sqrt{x^2 + a^2}) + 2a^3] \frac{P R^3 \delta 2\pi^2 \gamma n (\triangle \pm c)^3}{3g.60^2.33000}, \qquad (8)$$

and $$W = \frac{R^3 P^3 (\triangle \pm c)^3 A \gamma n}{2g \times 60^2 \times 33000}. \qquad (9)$$

For example: When the vessel is fast to the wharf,

Then $\frac{u'}{u} = 1 = (o + c)^3 = c^3 = 1$.

Knowing u; by an indicator card we obtain u', when in smooth water. Then $\frac{u'}{u} = (\triangle \pm 0)^3$ to find $\triangle$.

Knowing both u and $\triangle$; by another card taken under any circumstances we have $\frac{u''}{u} = (\triangle \pm c)^3$ to find c. In other words by an indicator card it is possible to tell the speed of the vessel in the engine room without any other measurement. This the writer has repeatedly done on board of various vessels.

The best proof of this is experiment. Of numerous examples, one will be sufficient to quote, viz.: the performance of the Chippewa at the dock and under weigh as recorded by Isherwood.

Power at the dock, . . .	140·04	Log.	2·1462521
Revolutions at this power, . .	52	52^3	5·1480099
u or power at one revolution at the dock, . .			$\overline{4}$·9982422
Power under weigh uninfluenced by wind, .	239·528	=	2·3793599
Revolutions 75, ...	75^3	=	$\overline{5}$·6251839
w or power at one revolution when under weigh, .			$\overline{4}$·7541760
			$\overline{4}$·9982422
			3)$\overline{1}$·7559338

Relative displacement under weigh, or $\triangle = \cdot 82917 = \overline{1}\cdot 9186446$

$\therefore (1 - \triangle)\,100 = 17\cdot083$ is the slip. Isherwood records the slip as 16·3 per cent. of the final pitch, which record is sufficiently near to the estimated result to avoid unfavorable comment. The variation in the rate of revolutions is found similarly.

$\overline{4}$·9982422

$\overline{4}$·7541760

3)0·2440662

1·206 = 0 0813554

That is the revolutions at the dock being unity, then under weigh they will be 1·206.

As a corollary: Since the power and displacement at the dock is in exact ratio to the power and displacement under weigh, it follows

that there is no loss of effect from slip. The writer has been mislead for years by this term, for its truth was accepted by him. Indeed it will shortly appear that there can be too little slip for economy.

The friction of the screw, like the friction of any other machine, is a factor of the pressure upon the surface and its amount is expressed by the modulus of friction multiplied by the work done by the machine, and we might write it $F = kW$. It is so small an amount that it is herein neglected.

In any screw the best possible diameter is the largest practicable. In Fig. 2 the curve is the boundary of the sin β at every position in radius, since the power to produce a given effect varies with sin β. Fig. 2 proves this proposition, because the sines are smallest at the periphery. For the same reason the area of the screw is to be placed as near the periphery as possible.

The thrust T of the screw is the force exerted by the screw upon the vessel in the effort to propel, and is measured by the equation $T = \frac{P \times 33000}{RP}$ and its equivalents. It is the sum of all the resistances experienced by the ship in her progress.

Slip is caused by these same resistances, therefore slip varies with the thrust. Since thrust is composed of the unit pressure into the area of the screw, slip varies with the unit pressure and inversely with the areas of the screw.

The best possible screw that can be placed in a vessel depends upon the area, and consequently upon the slip of the screw, as controlling elements. Because if the area is too great, too much water will be displaced without corresponding benefit to the effect. On the other hand if the area is too small the slip becomes too great.

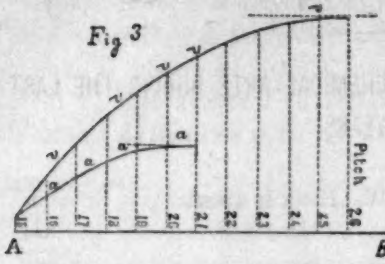
The best possible screw for a vessel is peculiar to that vessel; and that screw will not (except accidentally) be the best screw for any other vessel.

In the present state of our knowledge in order to obtain the best possible screw it is necessary to try one screw in that vessel so as to find by trial the slip of that screw.

From this data the slip of any other screw for that vessel can be found. By the trial the slip $(1 - \triangle)$ is known with its slip. Then $(1 - \triangle') = (1 - \triangle)\frac{A}{A'}$.

In order to find different and corresponding values for RP and A, we use the equations for the power at the dock; after finding $(1 - \triangle)$,

we can then plot $R\,P\,\triangle$ in a diagram to find the maximum value thereof. Fig. 3 is an example of such a diagram.



In this figure the revolutions are limited for the benefit of the air pumps, and variations in $R\,P$ are obtained by varying the pitch P. The values of $R\,P\,\triangle$ are laid off at right angles to $A\,B$ upon equidistant ordinates, each ordinate being numbered by the pitch used.

From the total value of $R\,P\,\triangle$ is subtracted 10 knots, so as to reduce the dimensions of the diagram. The curve a, a, etc., is the curve limiting the values of $R\,P\,\triangle$, upon the supposition that the views of this paper are correct; that is, that the slip varies with the area of the screw. At the pitch of 20 feet the results are best, which is entirely probable. The curve b, b, b, etc., supposes the slip to vary with the square root of the area, giving a maximum result at a pitch of 26 feet. This result is not so probable, being rather contrary to experience. It is certain however that in the case referred to a better result can be obtained than that at 15 feet, which is the trial position.

The idea of expanding pitches has not been dwelt upon. By Isherwood's experiments it was shown that when the water was deep the displacement of water by the screw was not aft, sidewise, centrifugally, or in any other direction than upward; that is, in the direction of least resistance. The idea of expanding pitches is therefore based upon a misapprehension of the circumstances.

Since when the vessel is under weigh no motion other than the slip is given to the water; it follows that there is no centrifugal action of the screw. The same thing follows from the fact that the water is displaced vertically. Any form intended to prevent centrifugal action, is therefore not only not beneficial, but, on the contrary, is prejudicial, because of increase of actual surface without an increase in the projected surface, beside interfering with the free delivery of the water in its path upward.

A true screw is therefore the best possible theoretically, and it has proved to be as good as any other experimentally.

After an immersion sufficient to prevent frothing is obtained, a greater immersion has no other effect than to increase friction; in proof of which see experiments recorded in *Naval Science*, for 1874.

Chemistry, Physics, Technology, etc.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. ci, page 421.]

Air-pump Sulphuric Acid Machine, by Edm. Carré, of Moislains.—We have still to mention a peculiar ice machine invented by the brother of the above-mentioned F. Carré, and also belonging to the class of absorption machines. Hitherto the idea has only been carried into practical execution on the small scale for domestic use. It was shown for the first time at Paris, in 1867, and has since been exhibited at Vienna. In principle it depends upon the cooling and freezing of water by its own evaporation in a vacuum—the well-known experiment of Leslie. E. Carré arranges his apparatus as follows:—A cylindrical vessel consisting of lead alloyed with 5 per cent. of antimony is half filled with concentrated sulphuric acid which can be kept in motion by means of a stirrer acting from without. With the upper empty part of the vessel is connected on the one hand an air-pump, and on the other an ascending tube fitted with a cock and slightly bent, so that a flask filled with water may be placed in its end, and an elastic band serving for a lute. All the joints are very carefully adapted so as to prevent all access of air. When the air pump is set in action the entire air is removed from the connected apparatus, the water evaporates and is absorbed by the sulphuric acid. After some time a crust of ice is formed in the flask, which increases more and more till the whole, which fills about half the flask, is frozen. The author succeeded in forming 340 grms. of ice

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

in forty-five minutes, 60 grms. of water having evaporated. The duration of the operation increases when the sulphuric acid grows hot and becomes diluted. By the use of 1½ litres of concentrated sulphuric acid, 10 flasks of ice, each amounting to 340 grms., can be obtained. The last flask required two hours in freezing, and 75 grms. of water were absorbed. The sulphuric acid had then taken up one-third of its weight of water, and its sp. gr. was 1·6. The cost of a flask of ice was 10 pfennige (about one penny, English) if the sulphuric acid is not put to any further use. In this form the apparatus is exclusively destined for the *Carafe frappée*, *i.e.*, to cool drinking water by means of ice. The writer does not think the machine fit for domestic use, since the smallest entrance of air renders it useless, and satisfactory connection materials are not easily met with. Concentrated sulphuric acid also is an objectionable article in the household.*

uch machines have been recently made by Eigel and Lesemeister, of Cologne. The duty of a machine of the kind described must, on the supposition that the sulphuric acid expended is recovered by means of concentration, be estimated at a very high rate. From a calculation which certainly was only approximate, it would appear that 17 kilos. of ice are produced per 1 kilo. coal used in concentrating the acid. If, in the continuous action of the apparatus, the concentrated acid running off could completely exchange its heat with the dilute acid to be introduced, the effect would be greater by one-third. This result considerably exceeds that of the ammonia machine. The manufacture of ice on this principle would offer certain advantages if the apparatus were differently arranged, since in its present form it is not suitable for lump ice. Perhaps instead of pure water a saline solution might be evaporated, which would be cooled down far below zero, and into which, as in other machines, vessels containing water might be plunged, and the latter might thus be indirectly frozen. The air-pump would require to be put into action only once in order to exhaust the air of the internal space. To open it would be needless, since the sulphuric acid can be introduced, and removed by means of pumps.

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* *Bad. Gewerbz*, 1868, 153. *Comptes Rendus*, lxiv, 897. *Dingler Polyt. Journ.*, 77 and 417.

III. *Production of Cold by Expansion.*

If a gas is compressed the mechanical power applied is converted into heat and the temperature rises. If equal volumes of different gases at a similar initial pressure are compressed to the same extent, a gas of lower specific heat increases in temperature more than one of higher specific heat, and that in a potentiated manner since its particles, in the first place, assume a higher temperature by an equal increment of heat, and secondly, since the hotter gas possesses a greater tension and opposes more resistance to compression, whence more heat is evolved. Different gases of equal initial temperature and tension, when compressed to an equal volume, not only attain unequal temperatures, but unequal pressure. The following table shows in what proportion atmospheric air of mean tension increases in temperature if compressed at an initial temperature of 20° C.

Pressure in atmospheres - - -	1	2	3	4.
Temperature - - - - -	20	85	130	163.

If a hot compressed gas is allowed to re-expand, always under full pressure, the heat is transformed into mechanical power, and a fall of temperature ensues in the same measure as the rise during its compression. If a hot and compressed gas is cooled down and then expanded, it falls below the initial temperature, and very great degrees of cold can be attained. Thus air at 2, 3, 4 atmospheres, cooled down to 30° C., and allowed to expand to 1 atmosphere yields respectively the temperatures of 25°,—53°,—70° C. It is pre-supposed that the air, like steam in an engine, works outwardly; if it rushes into an empty space the temperature of the whole mass experiences no change, since the heat lost by the initial expansion is reproduced by the impact of the molecules against the sides of the vessel. If the air drives before it a pressure smaller than corresponds to its own tension, *e.g.*, if, having been strongly condensed in a receiver, it escapes into the open air its fall in temperature is less than as stated above. On these principles depends the application of air to the production of cold and the preparation of ice.

Accurately regarding the various stages traversed by the air, the arrangement of an air ice machine would be, in principle, as follows:—The air is condensed in an especial cylinder up to a certain pressure, at which it is then forced into the cooling apparatus. Whilst it

here parts with its excess of heat, its volume, at the same pressure, becomes reduced in the proportion—

$$\frac{273+t}{273+T.}$$

Hence it passes into a second cylinder where expansion takes place; the processes taking place here in the reversed order from what ensues in the compression cylinder, and the effect agrees exactly with that of an expansion steam-engine. The air here becomes very cold and is forced by the return of the piston into the freezing chamber where the ice boxes stand. After passing through this apparatus it arrives anew in the compression-cylinder to repeat the same circuit. The expansion-cylinder here corresponds to the evaporation-receiver in other machines. The distinction, however, must be noted that but a small quantity of air is kept in circulation, whilst in other systems a large stock of the matter inducing the cold is present in the state of a liquid. It will be seen that the course of the conversions is exactly the same as in a "caloric engine," but in a reversed direction, and the performance of the one and the other may be calculated by the aid of the same formulæ. The writer has carried out such a calculation,* from which, it appears, that when the air, at an initial temperature of 20° C., is compressed to 3 atmospheres and then cooled down to 30°; the theoretical yield is 5 kilos. of ice per 1 kilo. coal consumed, whilst at 2 atmospheres the yield is 6 kilos. The production is in general terms inversely as the condensation of the air or the difference of temperature thereby produced. But, on the other hand, the dimensions of the cylinders for a given yield must be so much the larger the smaller the condensation which is to be applied, as appears at once on a close examination of the procedure. The actual performance of the machine may perhaps be considered equal to one-half of the theoretical yield. Hence it appears that the air machine is far inferior in its performance to the ammonia machine.† The reasons are the same which have been already advanced in the comparison of the ammonia and the ether machine. The efficacy of the machine may, however, be considerably increased, if, as we shall further explain below, the air is at once cooled during compression,

* *Bad. Gewerbz.*, 1869, Appendix Number.

† In consequence of the low specific heat of the air, relatively large quantities must be employed, whence the cylinders and the resistance of friction to be overcome are very large.

so that it cannot become heated, in which case the cost of compression is much reduced. An advantage of the air machine as compared with other systems is that no offensive or combustible substances are brought into play, and that there can occur no waste of a costly material.

An air machine is mentioned for the first time in 1863.* It was patented in England in April, 1862, by A. C. Kirk, of Bathgate. It consists of upright cylinders, the lower part of each being connected with the upper part of the other by a channel, fitted with a valve opening upwards. The pistons have valves opening downwards. The lower covers of the cylinders are kept cold by a stream of water, whilst the upper give off cold to salt water. According to the somewhat obscure description the action is as follows:—The piston of the cylinder *a* on descending compresses the air below it, and expands that above it, the compressed air being forced into the upper part of the cylinder *b*. On the ascent of the piston *a* the expanded air passes through the valve of the piston from the upper into the lower part of the cylinder, whilst the piston receives above at first compressed air from the lower part of the cylinder *b*, which, when the latter is emptied, begins to expand and to be cooled. The same processes take place in the cylinder *b*. Consequently one and the same quantity of air is always employed, which circulates from one cylinder to the other. It is asserted that 1 horse-power yields, in twenty-four hours, 106 kilos. of ice, the yield of the ether machine being 110·5 kilos.,= 2 kilos. ice per kilo. of coal. In Young's paraffin works at Bathgate there was at that time a machine which turned out in twenty-four hours 2 tons or 2032 kilos. of ice. The result is somewhat small; the cooling surfaces of the cylinders are certainly not large enough to take up heat and cold quickly and completely. Indeed a series of theoretical objections might be urged against the construction of the

* *Pract. Mech. Journ.*, 1863, 113. *Dingl. Pol. Journ.*, clxx, 241. Wagner, *Jahresbericht*, 1863, 568. However, a patent for an air ice machine was granted, in England to one Nesmond, of Bellac, in France, as early as 1852. It compressed air to 20 atmospheres by means of a hand air-pump in a vessel like a boiler placed in cold water. After cooling the air passed into a second vessel where were the substances to be cooled or the air to be frozen, and escaped thence into the open air. It was asserted that a man could force the air into the compression-vessel in eight minutes, and thus produce 8 to 10 lbs. ice per hour. The action of the apparatus was therefore intermittent and not economical, and indeed the whole arrangement left much to be desired in point of convenience.

machine, which is very simple. In 1864 it was announced that this machine was still at work in Young's establishment, producing a ton of ice with the consumption of a ton of coal, worth (then) four shillings. It was also declared that its efficacy was equal to that of the ether machine.* This would be a far smaller yield.

In 1869 the design and description of an ice machine constructed by F. Windhausen, of Brunswick,† were made public. It has only one cylinder, with a piston of the diameter of the height of the stroke. On one side of the piston there occurs compression and on the other expansion. The compressed air is forced through a cooler with a large surface, which serves at the same time as a reservoir for the compressed air. Whilst on one side of the piston the air is compressed it expands on the other. On the return of the piston the cold air is forced into the ice-chest, from which, when deprived of its cold, it is immediately drawn on the other side of the piston. That side of the long cylinder in which condensation takes place is surrounded with water as a cooling agent, whilst the other end is packed with a bad conductor of heat. The broad piston renders it impossible for an equalization of temperature to take place within the cylinder. For this purpose there requires an especial external arrangement for the admission and for the cutting off of the air which enters the expansion end. If the object is not to make ice but to cool spaces, the expanded cold air is forced directly into these, whilst the fresh external air is drawn into the compression end of the piston. As regards the performance of the machine nothing has transpired.

In the summer of 1871 the author saw at Berlin a powerful ice machine destined for New Orleans, constructed and experimentally set up by Windhausen. The construction was different from that above described, the compression and expansion cylinders being distinct, according to the scheme which we considered as most correct in principle, and took for the foundation of our preliminary investigation. It yielded air at —40° C., which was filled with abundant snow-flakes. As the compression cylinder constantly drew in fresh air, hygroscopic water was deposited in the cooler, where on account of the contracted space it could no longer remain in the state of vapor. From there the air, saturated with water, passed into the expansion-cylinder, and

* *Mech. Mag.*, 1864, 245. *Dingl. Pol. Journ.*, lxxiv.

† Windhausen, *Mech. Mag.*, 1869, 387. *Dingl. Pol. Journ.*, cxcv, 115. Wagner, *Jahresbericht*, 1870, 542.

in consequence of the cold produced by the expansion the greater part of the existing vapor was necessarily deposited as snow. This circumstance very much interfered with the working of the machine, as the friction of the piston was considerably increased by the snow, which also choked up the escape-pipes. The latent heat set at liberty acted also in opposition to the fall of the temperature even though the sum total of the negative heat units was not lessened. The piston was appropriately lubricated with glycerin. The author could ascertain nothing as to the experimental measurements made to determine the actual effect of this machine.

Since the beginning of 1873 Nehrlich and Co., of Frankfort-on-the-Main, make the Windhausen machine with two cylinders of one size only, with especial regard to the demand in breweries. It requires a 40-horse power engine, and is guaranteed to yield hourly 2500 cubic metres of air at temperatures of from —30° to —50°. If we assume that these temperatures refer to initial temperatures of from 10° to 30° the total reduction of temperature amounts to 60°, whence the amount of the negative heat units may be calculated as 50,000, corresponding at most to 400 kilos. of ice. If the production of ice were the object in view the same quantity of air might be made to circulate. A steam-engine of 40-horse power consumes hourly 80 kilos. of coal; consequently 1 kilo. of coal would give 5 kilos. of ice—a very favorable result. Such a machine, including the engine, cost in 1873 66,000 marks (£3300).

L. Mignot,* of Paris, in 1870, constructed also an air ice machine with distinct compression and expansion cylinders. It is distinguished from that of Windhausen by the arrangement that a small pump injects water into the compression-cylinder, and that the air in the condenser sweeps over open water. This arrangement is, without doubt, advantageous. The labor of compression is much reduced when the temperature of the air is kept low. The water cannot have an injurious effect in the air since the cooled and compressed air is in any case saturated with moisture. It may therefore be expected that the compression of the air will be effected at a less cost, and its complete refrigeration will require a smaller condenser. Particulars concerning this machine have not transpired. The more recent Windhausen machines are also provided with an injection apparatus.

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* L. Mignot, *Mech. Mag.*, Dec., 1870, 404. *Dingl. Pol. Journ.*, cxcix, 362. Wagner, *Jahresbericht*, 1871, 696.

According to experience hitherto, the air machines seem better adapted for the immediate application of cold air than for concentrating and storing up cold in the form of ice, in which respect they fall too far short of the ammonia machines. They may probably be found serviceable in breweries for cooling cellars. Motive power is always to be found in such establishments with which the air-pumps can be readily connected. The introduction of cold air into the cellars secures the further advantage that they are kept very dry by means of this air, which during its compression and expansion has been to a great extent deprived of its moisture, and hence no mould is formed. Cooling with ice, on the other hand, saturates the air of cellars with moisture, and keeps it stagnant. The whole process can be carried on in breweries at a relatively small expense, as in such establishments much heat and especially much hot water is required, and thus both the escaping steam and the hot water obtained by cooling the compressed air can be utilized. An air machine supplied by Merlich and Co. to Hildebrand's brewery at Pfungstadt, near Darmstadt, has given for a year very satisfactory results. The principle of the air machine seems also especially adapted for ventilation where it is desirable to combine reduction of temperature with renewal of the air, as in hospitals, public rooms, and steamships. Here a trifling expansion and a small degree of cold would suffice, and hence the working cost would appear relatively low. We may look forward with interest to the further development of this subject.

We have still to make mention of a more extended theoretical investigation which Linde* has given to the public on the "withdrawal of heat at low temperatures by mechanical agencies." The main result which he has arrived at in the way of calculation—which, however, appears at once on an attentive physical consideration of the changes that take place—is that for the economical working of ice machines the temperature of the body used as a medium during expansion must not be lower, and during compression not higher, than is absolutely necessary. This condition has hitherto been frequently overlooked, and ignored. Whilst it has frequently been said, in explaining the merits of an ice machine, that it works at such or such low temperatures, the very opposite should be the case; it should be shown that the machine produces ice without requiring a temperature far below

* Linde, *Bayer. Industrie u. Gewerbeblatt*, July, Nov., and Dec., 1870.

the freezing-point of water. The above-mentioned praise is merely a certain proof that the machine consumes much power needlessly. Certainly in this case the machine may be smaller and the first outlay easier, but this advantage generally vanishes in comparison with the drawback of increased working charges. Linde proves by calculation that in a theoretically perfect machine, which produces ice at —3° from water at +10° C., 1 kilo. of coal should yield 100 kilos. of ice. He combines also with his theoretical researches a critique on all ice-machines hitherto constructed. All makers of such machines should make themselves thoroughly masters of the principles here developed, which would keep them from going astray.

In 1873* J. Armengaud communicated certain theoretical speculations on air-machines to the French Academy, which, however, contained nothing essentially novel. He lays especial stress upon the importance of cooling the air during compression by means of water. The difficulty of effecting this by means of water injected in the moment of compression he overcame by introducing into the air, as drawn in, water, by means of Gifford's injector, probably as fine spray. According to its experiments it is most advantageous to work with a degree of expansion =2, in which case the power exerted, in proportion to the cold produced, is only half as great when the refrigeration is carried on during compression as if executed previously.

Nature of Artificial Ice.—Ice rapidly produced, at a very low temperature, is quite opaque and of a milky white. From this appearance —so different from the vitreous, transparent aspect of natural ice— the strangest conclusions have been drawn as to its behavior. Sometimes it was assumed to be more and sometimes less permanent, sometimes to have more and sometimes less cooling power than natural ice. The truth is that artificial and natural ice differ merely in appearance. A piece of the former just taken out of the machine is of course colder than a block from the ice cellar, and consequently melts rather more slowly on exposure to the air. Equally large pieces of natural and of artificial ice, at the same temperature, melt with equal speed under similar external conditions, and exert equal refrigeratory powers.

(To be continued.)

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* Armengaud, *Comptes Rendus*, lxxxvi, 626. Dingler, *Polyt. Journ.*, ccviii, 174

Evaporation of Liquids Aided by the Infusion of Air.—By a communication from M. Ed. Moride, of Nantes, France, published in *Les Mondes* (Paris), May 18th, 1876, the following account of experiments in evaporation in the concentrating of brine, at salt works, and of the juice of the beet-root in the process of sugar making, is given.

An apparatus constructed by MM. La Pommeray and Pinel has been placed at the salt-works of Croisic, belonging to MM. Benoît. It has worked with great advantage, producing much economy in time and a saving of nearly 40 per cent.

At the Etienne sugar refinery the method has been applied in the working of beet-root juice to the weak liquor of 5°, as well as to syrup of 25° density, without alteration of the juice or change of color. Both the raw juice and the syrup have been concentrated nearly to 42° density by a temperature of 80° to 86° centi. (176° to 187° Fah.), and have crystallized perfectly without any greater production of glucose than accompanies other methods of working. The evaporation progresses at the rate of an increase of density of 5° per hour, between 6° to 25°, when it is accellerated to the rate of 6°, 7°, 8° and 11° of concentration per hour.

At the A. César refinery the apparatus for infusion of air has been applied to a *vacuum pan*, and works perfectly, only that the vacuum cannot be maintained constantly except at 45° centi. (103° Fah.); otherwise, by admitting less air the vacuum can be raised, but the temperature will then be increased, to the detriment of the formation of a regular grain.

The sum of the results of the experiments in sugar making is—

1. That the "insufflation" (infusion of air) augments considerably the evaporation of a liquid.

2. That this method procures an economy of fuel of nearly 40 per cent., together with much saving of time, so great as to permit an ordinary boiler of evaporation to accomplish *five times* the usual results.

3. That the "insufflation" is without injurious action upon the sugar solutions, that it neither affects the color nor inverts the crystallizable sugar.

It is demonstrated to be possible then, with all security, to apply this novel method of evaporation to sugar-juice nearly to 35° or 40° of density; but the termination of the boiling may be effected in a vacuum pan, as is ordinarily done, or may be effected in free air.

NOTE BY THE EDITOR OF THE JOURNAL.

The method of "insufflation" and evaporation referred to in the preceding article is simply the blowing of streams of air, not necessarily heated, into a liquid warmed by some usual means to some desired temperature, which may or may not be the boiling point of the liquid. The active circulation promoted by the levity of the air-bubbles and the extended surface which is given for the evaporation of vapor to take place from, is supposed to greatly increase the efficiency of the heating surface to dispense heat to the liquid, by increasing the *difference* of temperature of the liquid where it comes in contact with the heated surface. The claim of saving of fuel, that is, of effecting a greater evaporation by the same quantity of heat, would seem to need more positive evidence before obtaining belief than is given by assertion, for the admission involves the establishment of new laws in physics, but the possibility of accelerating the process of evaporation by the method can be readily conceived and admitted in moderate degree; certainly, however, not that the same heating surface could be made practically efficient for "five times the usual results."

The familiar process of cooling a hot drink by blowing upon it, is the readiest example by which "evaporation by insufflation" can be comprehended, and although the process of *drying* or *desiccation* by means of currents of air is very generally practiced, yet the corresponding performance of evaporating a liquid by the same method is thought to be novel. In viscous liquids the application of this method would seem to have an absolute practical value, even if the excessive claim for merit in economy of fuel were found to be unwarranted.

The Production of Potash.—The production of potash commercially, has entirely changed aspect within these last twenty years. Prior to that time wood ashes were exclusively employed in its manufacture, but now more than half is procured directly from mineral sources. This is principally owing to the fact that the immense salt mines of Stassfurt have been found to yield a profitable supply of potash, and the knowledge of this fact has given a new impetus to saline deposits wherever they occur.

GREAT WESTERN RAILWAY.

The following observed speeds of a regular railway train in England is extracted from the correspondence of the *English Mechanic* April 19th 1876.

Miles.	Stations.	Arrival.	Departure.	Speed.
	Bristol		2·26	
44¾	Taunton	3·18	3·20	51·6346
75½	Exeter	4·0		46·125
				97·7596

= 48·8798 average.

Or average for whole distance = 118½ miles + 75½ miles = 194 miles (11·45 to 4 o'clock) = 255 minutes — stops (10 + 2 + 5 + 2) 19 minutes; ∴ average = $\frac{194 \times 60}{236}$ = 49·32203 miles per hour.

Miles.	Stations.	Arrival.	Departure.	Speed.
	Paddington		11·45	
5¾	Ealing	11·54		38·8333*
7½	Hanwell	11·56		52·5
9½	Southall	11·58		52·5
11	Hayes	12·0		52·5
13¼	Drayton	12·2 1/12		64·8
16¼	Langley	12·5¼		56·8421
18½	Slough	12·8		49·0909
22¾	Maidenhead	12·13		51
31	Twyford	12·21		61·875
36	Reading	12·27		50
41½	Pangbourne	12.33		55
44¾	Goring	12·36¼		60
47¾	Moulsford	12·39		65·5555†
53¼	Didcot	12·45		55
56½	Steventon	12·49		48·78
60	Wantage	12·52¾		56
64	Challon	12·57		56·4705
66¼	Uffington	12·59½		54
71½	Shrivenham	1·5		57
77¼	Swindon	1·12		49·2857
				1086·5330

= 54·32665 average.

miles per hour.

* Minimum. † Maximum.

"THE PHYSICS OF THE ETHER."*

By WILLIAM B. TAYLOR, Washington, D. C.

(Continued from Vol. ci, p. 413.

In regard to the still more recondite phenomena of *chemical* elective affinity, Mr. Preston is equally at home, and equally self-complacent.

"The vast variety of wave period observed, points all the more convincingly to the fitness of the molecular vibrations as the regulator of the complex and varied effects exhibited in the movements of molecules in "chemical action," or those diverse molecular movements which belong to the science of chemistry. . . . In viewing the phenomena of the movements and mutual actions of molecules as a physical problem, it really is not conceivable that anything could be more admirably adapted to produce the effects than the vibrations of the molecules, which also, by variation of wave period, are capable of building up the almost endless variety of chemical compounds," (pp. 32, 33).

That is, molecules agitated with a red vibration of the ether, will naturally be made to "approach" other molecules similarly timed; so yellow moving molecules will affect each other, while extra violet molecules will in like manner only accept harmonious partners in the chemic dance. And while this special selection, whether of ethereal or of molecular periodicities, is in action, there is still sufficient of the unselected vibrations to secure gravitative and cohesive "impulsions," for the ethereal reservoir of motion is by assumption infinite and inexhaustible.

As to the actual measure of the tension of chemical affinity, Mr. Preston has calculated that a hydrogen molecule in combining with an oxygen molecule to form water, supposing it to move through one millionth of an inch, exhibits an energy which "is 424 billion times greater than the weight of the double hydrogen molecule, or the value of gravity acting upon it," (p. 67), and that accordingly,

* Mr. Preston has recently published a *résumé* of his lucubrations in a series of eight articles, under the rather inappropriate title of "The Origin of Motion,"—in the columns of our excellent English contemporary "*Engineering*," for January 7th, January 21st, February 4th, February 25th, March 17th, March 31st, April 28th and May 12th, of the present year.

"If we take a grain of water [one drop], then the value of the strain required to separate the molecules being 424 billion times the weight of the hydrogen molecules, and the total weight of the hydrogen molecules in a grain of water being one-ninth of a grain, we have accordingly 424 billions $\times \frac{1}{9}$ grain, $=$ 3 million tons in round numbers*. . . . As before remarked, a millionth of an inch being unquestionably too large as an estimate for the distance traversed, the result arrived at for the absolute value of the strain will be by so much less than the actual fact," (p. 68).

With this general conception of the chemical phase of ether motion, let us see how Mr. Preston contrives to produce an explosion within a loaded gun, by ethereal vibration.

"Considering the state of the case previous to the discharge, it is well first to have a clear conception of the fact of the ether pervading with the utmost facility the body of the cannon, the ether occupying the molecular interstices and surrounding the molecules of the metal, so that, therefore, the slightest difference of the ether due to any disturbing cause, would immediately readjust itself across the body of the gun. . . . We observe, therefore, before the discharge, the ether enclosing its intense store of motion pervading the body of the cannon, and inserting itself between every molecule of gunpowder, ready to part with a portion of its motion at any instant. . . . We note, therefore, an ingeniously disposed and delicately poised train of matter, at present in a state of dynamic equilibrium, the whole pervaded by a physical agent of exhaustless energy from which it is only necessary to divert a small portion in order to cause the propulsion of the shot. The blow struck upon the percussion cap, by urging a few of the vibrating molecules into proper proximity, is sufficient to upset this equilibrium of motion and bring the ether into action, the motion passing from the ether through the train of matter to the shot, and thence to the ether (in the waves emitted by the incandescent gases, the work of the shot, etc.) in a cyclical process. . . . During the time of the explosion, the ether particles in the bore of the gun lose a certain fraction of their normal velocity by transference to the molecules of gunpowder, which loss of motion, if it

* It may be well to notice here, that the average distance of molecules from centre to centre, in the liquid or solid form of matter, has been successively estimated at values not very far removed from the 200th millionth of an inch, by Waterston, in 1857; by Loschmidt, in 1865; by Stoney, in 1868; by Thomson, in 1870; and by Maxwell, in 1873.

continued without renewal, would conduce to a reduction of the ether pressure in the interior of the gun; so that the inference is necessary that on the instant of the disturbance of the equilibrium of the ether pressure by the motion transferred to the first few molecules of gunpowder, a *readjustment of pressure* commences to take place across the body of the gun in the form of a wave, the free communication existing with the external ether rendering it impossible for any appreciable difference of pressure to accumulate," (p. 101). "The molecules of gunpowder merely serve as the convenient mechanism to transmit the motion of the ether to the shot, for the gunpowder, like the shot, has no motion of its own, and therefore must have the motion imparted to it. The ether, on the other hand, does not require to have motion imparted to it, since it already has motion. The ether is, therefore, the only competent source of motion, or the ether transfers motion which it already has through the gunpowder to the shot; the sum of motion thereby remaining constant," (p. 103).

So to give the required dynamic energy (beyond that of ordinary temperature) to the material particles of the gunpowder, it is necessary that the illimitable store of motion in the ether should suddenly be called upon; and as it could not be supposed to enter at the muzzle of the gun at the moment of discharge, it has to pass without ceremony through the walls of the gun; although Mr. Preston has previously told us that every molecule of iron in the gun is held firmly in its relative position by *statical* vibrations of the intervening ether, inducing a rarefaction whereby the external impacts of the ether exert an excess of coercive dynamic pressure—say of 10 tons to the square inch. But what becomes of this differential coercive bond when the violent influx of ether pressure is passing through transversely to these interstitial stationary vibrations?

Such is the wonderful physical philosophy by which the tenacity of guns is established, and the disruption of their discharge simultaneously effected. Of *static* force Mr. Preston has no conception, for with him motion is everything, and everything is motion. "Potential energy" in such a system is as inadmissible as "action at a distance." How can a body at rest possess any power? (p. 9). Every child knows that a thing cannot act where it is not; although its apple *does* slip from its fingers without strings from below, and without "impulsions" from above. And every child of course knows that when a clock is wound up, *with the pendulum at rest*,

"Unless *motion* be imparted at the time, energy cannot be expended at all; for to expend motion without imparting motion would be to annihilate energy. Indeed, the motion imparted is itself the measure of that expended, and is the sole cause of its expenditure; *i. e.*, motion can only be expended in the communication of motion, and in that fact lies apparent the principle of the *Indestructibility of Motion*," (p. 93). "The process of coiling a spring, as by the winding up of a clock for example, in which act the vibrating molecules of the spring are displaced, affords another illustration of work consisting in the communication of motion to the ether," (p. 99).

"Now it follows from the principle of conservation, that the previous existence of motion is the absolutely essential condition in order for motion to be developed, for unless motion previously existed, motion could not be expended in the act of developing motion," (p. 12).

So whether gunpowder be kept in a magazine for an indefinite number of years, or a powerful spring be placed under severe tension with its detent unreleased; whether the Great Eastern is held securely by its anchored cable during a storm, or carbon deoxidized by solar energy many million years ago, is reposing in unworked coal-fields, in each and every case the store of potency is simply, *motion!* When coal is finally mined and placed within the furnace of a steam-engine,

"All the motion developed at combustion, and imparted to the ether in the form of waves of heat, comes from the ether at the time of combustion; so that the process of combustion might be continued indefinitely without the slightest absolute gain of motion; or the interchange of motion constituting combustion is quite independent of the fact whether energy was expended in the previous act of separating the carbon or not," (p. 96).

"The interchange of motion may be said to form the whole basis of the great principle of conservation, for the very idea of the interchange or transference of motion, itself precludes all idea of the possibility of the annihilation of motion; or the only possible method of getting rid of the motion of a mass of matter is by transferring that motion to another mass or masses," (p. 89).

This radical fallacy of the "indestructibility of *motion*" has, unfortunately, gained a considerable acceptance, and has received the support of names much higher than that of Mr. Preston. Even so

clear and generally correct a thinker as Herbert Spencer has permitted himself to write a chapter on "The Continuity of Motion," (*First Principles*, 1st ed., part ii, chap. 6).

The hammer motion expended in making a horse-shoe has but a relatively small portion of it converted into the vibratory motions of sound and heat. The greater portion, and the whole useful portion of the hammer blows, is *consumed* in simply displacing iron molecules in a desired direction; to effect which, a very considerable amount of *static* tension has to be overcome in the resistances to a disturbance of position offered by the particles; and this molecular resistance constituting the hardness of the material, is precisely what gives the finished product its useful function. So when the ram of a pile-driver is laboriously raised to its highest position, and there held by the grapple, what has become of the motion employed in raising it? Has the arrested lifting power been converted into heat vibrations, carefully conserved and patiently waiting to be re-converted into falling motion when the director shall release the detent? Surely such an idea can hardly be entertained for a moment by an intelligent physicist. Supposing that for sufficient reason it is determined not to let the ram fall till the following day, where then is the motion of elevation hiding itself all this time?

Mr. Preston, recognizing no equivalent of force conserved in the "potential" state of matter raised to a mechanical advantage of *position*, at which time all effective motion has ceased and forever disappeared, supposes that

"At the particular instant when the machinery was first started, motion was derived from the ether without being simultaneously transferred to the ether; this relatively small amount of motion (representing the motion of the machine) remaining abstracted from the ether so long as the machines are in motion, but when the machines stop, this motion is returned to the ether in the form of waves of heat," (p. 98).

In this illimitable ocean, therefore, the waves of motion are supposed to remain in action, until, in the case of the pile-driver, at the slipping of a trigger they suddenly reappear in the descending ram.

One is tempted to ask, what is the special necessity or advantage of this circuitous "transfer of motion," this "cyclical process," in every mechanical effect? Why not devise some way of more

directly availing ourselves of the exhaustless store of motive power ever present in the infinite depths of ether, and ever ready to respond with the quickness of light to the tremblings of matter? Why not dispense with the intermediate *ram?* The stock of coal is very finite; the stock of ether energy—infinite. The same thought appears to have occurred to the ingenious author of the "Physics of the Ether."

"If the vibratory motion of molecules could be brought under control, and thus be temporarily got rid of by utilization in any way, then the above result would be attained, or the molecules would separate without the performance of work; as we have before pointed out that there are certain considerations which would indicate that this result is actually attained in nature, in the disintegration of matter at a low temperature," (p. 96).

"Perhaps a partial reduction of the vibrating energy might help, but we are not restricted to discrete molecules, and possibly the reciprocating movements of approach and recession of masses under the action of the ether in the 'electric' and 'magnetic' phenomena, might be found more subservient to this special object, and thus the enormous stores of motion present on all sides be made of more practical avail than by the present methods of utilization. At all events, it appears an anomaly that motion should be only obtainable from a source on the condition of the expenditure of an equivalent amount of machinery," (p. 97).

The anomaly is obvious on the assumption that force and its offspring motion are not derived from the molecules of sensible matter, but have their origin in an entirely *external* source. If the power antecedently derived from the ether by a mechanical or chemical train were at each instant precisely equal to the power expended in useful work, we should have a very satisfactory perpetual motion. Although in terms Mr. Preston accepts the modern doctrine of the "conservation of energy," yet, as this is expressly applied by him to the infinite store normally existing in the *ether*, and as the quantity of energy manifested by matter is declared to be variable (pp. 95, 96, and 98, 99), it is too obvious for remark that the grand theorem becomes practically valueless, and that all the attempts hitherto made to deduce the principle from the deportment of sensible matter are utterly illusory and fallacious.

But what is the *evidence* adduced by the author to give plausibility to his stupendous fabric of conjecture? So far as can be discovered,

the *a priori* argument already quoted: "Since a rarefaction of the medium constitutes the only possible physical means by which an 'attraction' (approach) can be produced by vibration, . . . it therefore follows that a stationary vibration of the medium can be the sole physical cause concerned in producing an attraction," (p. 49). Alas, this "sole physical cause" has not even the indirect support of fitness, or of congruity. The supposition is not in conformity with the most obvious characteristics of molecular physics; its postulates are not even consistent with each other. The conditions required for statical phenomena are incompatible with those required for dynamical phenomena.

When we are told that *In principio erat Motus*, rendering futile any inquiry into the origin of this "phenomenon,"* that this phenomenon, though usually "concealed" in the impalpable ether (as the molecular movement of normal temperature is in the atmosphere), becomes *sensible*, as in some sense a function of material masses—that it is not strictly a function of mass, since its energy is a product of the amplitude of vibration, or, as we might say, of thermal activity; and, accordingly, that with the lowering of this activity, the differential of external "impulsion" is reduced, and the tendency to "approach" thereby diminished, whether between molecules or masses,† we see, at a glance, that such presentations are in no respects accordant with the ascertained system of nature; and that they fail, signally, to give us any approximate representation of the *coercive forces* actually manifested in matter.

The subject of tides has not been specifically discussed; but any scheme of physics requiring the affirmation that the water of the ocean is lifted by ethereal "impulsions" from beneath, which have

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* Mr. Preston does indeed make the concession, though with a different intent, that "if all physical effects be effects of 'motion,' then in principle, the one fundamental 'cause' for investigation must be the *cause for motion*, or the cause determining the vast variety of motions constituting physical phenomena. To admit, therefore, a theory which would do away with the necessity for investigating the *cause* of motion, would be to admit a principle which, if carried out universally, would close the field for physical research altogether, or which would assume that physical effects were inexplicable," (p. 5).

† "Since, when a physical cause ceases to exist, the effect also ceases, it follows that at the absolute zero of temperature (absence of vibrating energy) the general phenomenon of 'cohesion' including the aggregation of molecules in 'chemical union,' would cease to exist." (*Ether*, p. 64.)

passed through the solid portions of the globe in the direction of the lunar column of stationary ethereal vibrations, may be at once dismissed, as being too whimsical and chimerical to deserve serious attention.

Mr. Preston has professedly undertaken the difficult, but most important, discussion of the "physics of the ether." But what is the "ether?" or rather, what is the foundation of the conception now received into science under that name? The demonstration that radiant light and heat are but forms of vibratory movement, seems to render necessary the presence of a material medium in celestial spaces, capable of receiving and transmitting such movement. It transcends all our experience, and all conceptions derived therefrom, that motion (defined as changing position) can exist apart from material substance; or, in other words, can be transmitted through a vacuum. Hence, the inferred necessity of a pervading inter-stellar medium, having the rarity and elasticity requisite to perform this office. Without *such* supposed necessity, the notion of this illimitable ocean of "ether" would probably be abandoned at once, by almost every astronomer and physicist; for it is really a greater strain upon the scientific imagination, than even distant attraction itself. Above all things, then—*first* of all things—the "ether" must be *luciferous*.

Now, Mr. Preston, in his enthusiasm of ether, has so overburdened it with duty, that he has quite impaired its primal function of transmitting in *straight lines*, with *uniform velocity*, and in *determinate planes*, a succession of undulations. By his hypothesis, celestial space (at least within the solar system) is traversed by moving lines of *stationary vibrations*, exhibiting a permanent *rarefaction* to render possible the differential of dynamic pressure, which constitutes the foundation of his system. It is hardly necessary to remark, that in a medium so constituted, luminiferous waves could never have either a uniformity of velocity, or a uniformity of direction. Stellar occultations, instead of being mathematically determinable, would be subject to incalculable anomalies: "aberration," instead of being uniform, would be scarcely ever self-comparable; and from the eclipses of Jupiter's satellites, we could never have determined the actual velocity of light.

Our author's hypothesis assumes a normal, aboriginal, intestine motion of the ethereal atoms, of inconceivable energy, constituting the

primæval fund or reservoir of "force." The received theory assumes the ether to have no motion whatever, excepting that impressed upon it by the vibrating molecules of stellar and planetary matter.

And, instead of the analogue of a dynamic gas is so unhesitatingly adopted by Mr. Preston as the type of ethereal constitution, thoughtful physicists have been disposed to accept the suggestion, that the phenomena of "polarization" point rather to a constitution of atoms held in stable equilibrium by intense mutual *repulsion;* and more resembling, therefore, the character of an infinitely attenuated jelly, than of a mobile gas. (Herschel's *Familiar Lectures.* Lect. vii, sect. 67.)

In his preface, Mr. Preston announces that

"The present work, the result of much thought and careful study, is intended to afford an explanation or insight into the mode of working of an important series of physical phenomena at present referred to the theories of 'action at a distance,' and 'potential energy.'" (Pref., p. 1.)

The conclusion reached in this review, is that the author, like all his numerous predecessors, has failed utterly to accomplish his intended object;* and that his proposed "physics of the ether," is really but a travesty of gaseous dynamics under impossible conditions. That his work has been "the result of much thought and careful study," cannot be doubted; adding, however, but one more example of ability misapplied, and of labor entirely thrown away. The author adds: "The first part of the work contains an argument designed to prove that . . . . 'potential energy,' or an energy *without motion,* is inadmissible." (Pref., p. 1.) *Per contra,* no physical phenomenon is better established, than that *Motion* (whether of molecules or of masses), is constantly originating from that which is *not* motion; *i.e.,* from static *position*—as in combustion and explosion; in the galvanic battery; in the equipoised avalanche; in the over-loaded suspension bridge; in the bursting water reservoir. These simple but pregnant facts, outweigh all suppositions; and for such examples

* A somewhat similar discussion is the subject of a volume entitled "*Matter and Ether:* or, the Secret Laws of Physical Change." by Rev. Thomas Rawson Birks. 12mo. Cambridge. Macmillan & Co., 1862. A much more elaborate exposition of the ethereal hypothesis of molecular Attraction, Gravity, Electricity, Galvanism and Magnetism, will be found in *The Mathematical Principles of the Physical Forces.* By Prof. James Challis, pp. 996, octavo. Published at Cambridge and London, in 1869. Several of the mathematical discussions were published ten years earlier, in the *Philosophical Magazine.*

of reposing power, no better name has yet been devised than "potential energy," or "static force." In short, "motion" is, *in every case*, a mutable resultant; and cannot, therefore, be a primæval "cause." In diametrical opposition to the fundamental kinetic postulate of our author, we announce the inductive thesis, that motion, of whatever form, is *invariably* the progeny of static force.

When Mr. Preston, from his supposed plane of higher wisdom, somewhat magisterially asks: "Can it be said (and if so, in what respect), that a clearer idea admits of being formed, of the *means* by which motion is produced, when it is referred to 'action at a distance,' and when it is referred to 'psychic force'?" (p. 3)—the honest and intelligent student of nature, distinctly avows that he has no idea whatever "of the means," clear or otherwise—certainly no "clearer idea," therefore, in the one case than in the other; and the one action is rejected, while the other is accepted—*solely* as the outcome of a life-long and unbroken induction.

The basis of all real knowledge is experience. If we know that all matter tends to "fall," we know it *only* as a result of universal experience. If we do *not* know why or how this "falling" tendency exists, it is because we have absolutely no experience to guide us. And where observed facts fail to sustain our speculations, or anticipations, there the modesty of true science requires us to frankly confess our ignorance, and to acquiesce in *the simplest statement of the actual phenomenon;* without presuming to venture on metaphysical dogmas as to the possibilities of natural action being measured by the limitations of existing human conception. Should any conclusive evidence be hereafter discovered, that the "ether" itself is a *myth*, then we should be driven to the admission, not only that gravitative influence, but that even vibratory motion is an *actio in distans;* however "inconceivable" the proposition.*

* Prof. Faraday seemed at one time disposed to accept the idea of pure "force" being capable of exciting vibration, as well as motion. In 1846, he said: "The view which I am so bold as to put forth, considers, therefore, radiation as a high species of vibration in the lines of force which are known to connect particles, and also masses of matter together. It endeavors to dismiss the ether, but not the vibrations." (*L. E. D., Phila. Mag.*, 1846, xxviii, 348.) Light has a known rate of progression, however, so that a ray starting from the Sun, reaches the planet Mercury in 3 minutes, Venus in 6 minutes, our Earth in 8 minutes, Mars in 12 minutes, Jupiter in 41 minutes, Saturn in 1 hour and ¼, Uranus in 2 hours and ¼, and Neptune in 4 hours. No such *propagation* exists in the case of gravity.

Perhaps no more fitting conclusion to this unduly prolonged discussion, could be made than to select some of the precursors of Mr. Preston in this field, if only to keep him in countenance, though this is scarcely necessary. Almost every year, for the past forty years, one or more essays or treatises have been submitted to the French "Academy of Sciences," designed to offer a full explanation of the origin of force in general and of gravitation in particular. Omitting "electrical," and other more visionary systems of the universe, the following list, taken from the *Comptes Rendus* of the Academy, represents only the announcers of ethereal pressure as the physical catholicon:

Mr. Schweich. "Theoretical Ideas of Gravitation." (*C. R.* 1838, vii, 83.)

Mr. Reichenbach. "On Universal Gravitation." (*C. R.* 1838, vii, 973.)

Mr. Darlu. "Memoir on the Causes on Gravitation." (*C. R.* 1839, viii, 338.)

Mr. De Tessan. "On Universal Attraction." (*C. R.* 1840, xi, 481.)

Mr. Lamé. "On the General Principle of Physics." (*C. R.* 1842, xiv, 35; "Lessons on Elasticity," 1852, xxxv, 459.)

Mr. De Boucheporn. "Researches on Physical Laws." (*C. R.* 1849, xxix, 107; "On the General Principle of the Laws of Astronomy and Physics," 1853, xxxvi, 417 and 533.)

Mr. Guynemer. "On the Impulsion of an Ethereal Fluid." (*C. R.* 1853, xxxvi, 593; 1854, xxxviii, 942.)

Mr. Durand. "A Theory of Gravity and Magnetism. (*C. R.* 1856, xliii, 165.)

Mr. Hermite. "On Universal Gravitation." (*C. R.* 1857, xliv, 330.)

Mr. Allouin. "Hypothesis of the Causes of Universal Attraction." (*C. R.* 1859, xlviii, 269.)

Mr. Nardini. "On the Nature of Cosmic Forces." (*C.R.* 1862, lv, 917.)

Messrs. F. A. E. and Em. Keller. "Memoir on the Causes of the Effects attributed to Universal Gravitation." (*C. R.* 1863, lvi, 530.)

Mr. E. Martin. "On a Substantial Ether, as one of the Grand Principles of Physical Nature." (*C. R.* 1863, lvi, 1211.)